THE HISTORY OF THE RISE AND PROGRESS OF GEOGRAPHY.

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BY

The Rev. JOHN BLAIR, LL. D.
Late Prebendary of WESTMINSTER.

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ON THE

RISE AND PROGRESS

OF

GEOGRAPHY.

IT muſt be obvious to every one, that ARTS and SCIENCES, when repreſented only in their more ripened State of Improvement, can never communicate a full Degree of Information, unleſs at the ſame time the ruder Stages through which they paſſed, before they arrived at that Degree of Per-

fection, are minutely traced and known. A young Architect would never attain to be Maſter of his Art, if he had only ſeen Buildings, however magnificent, after the Fabricks were completed. For then he could have no Opportunity of obſerving the Breadth or Depth of the Foundations which are neceſſary for carrying ſo great a Weight; he could know nothing of the Figure and Contrivance of the Frames by which the Arches and Vaultings were executed; the Manner of fixing thoſe Beams which bind the different Parts of the Walls and Roof together, and all the various Application of Tools and Engines, Ladders and Scaffolding, by means of which the Efforts of Art and Labour were united to complete the Pile. For when the Superſtructure

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is finiſhed, then all theſe various Implements of Mechaniſm are removed, like Rubbiſh, from the Spot, and many of the ableſt Exertions of Skill in the Builder lie covered and out of Sight.

Geography therefore is, in this Reſpect, like every other Science, whoſe imperfect Beginnings ought to be traced, and the Time and Manner pointed out in which it received its gradual Improvements. For though it is far from my Intention to prefix any Syſtem of Geography before the few Maps which are now publiſhed by by way of Illuſtration of my Tables of Chronology; yet having found but little Satisfaction in any one Author, though I have looked into moſt of them who have profeſſedly wrote upon this Sub-

ject, I have, for my own Amuſement, collected and digeſted from different Writers, both ancient and modern, ſuch Particulars as I thought moſt intereſting for giving the Outline of this Hiſtory of Geography, hoping that the Leiſure and Abilities of others, more converſant in this Branch of Knowledge, may be prompted to ſupply more amply this *Deſideratum* in the Hiſtory of Learning.

It appears that the early Geographers, being deſtitute of mathematical inſtruments and of aſtronomical Obſervations, began firſt to determine the Situation of Places according to Climates; and they were led to fix upon thoſe Climates from the Form and Colour of certain Animals which were

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to be found in thoſe different Countries. The Appearance of *Negroes*, or what they called Æthiopians, and of the larger ſized Animals, ſuch as the Rhinoceros and Elephants, ſuggeſted to them the Line of Diviſion where the Limits of the Torrid Zone began towards the North, and ended towards the South. For Reaſon, ſaid they, points out to us, that ſimilar Things appear in the ſame Temperature of the Elements; and that whether they were Animals or Plants, they are produced according to the ſimilar State of the Air or Climate under the ſame Parallels, or a like Situation equally diſtant from either Pole *.

* Ptolemæi Geogr. lib. 1. cap. 9.

This groſſer Manner of dividing their Climates, muſt be conſidered as the firſt rude Outline of Geography in the more illiterate Ages of the World. For another Method was ſoon adopted by the Egyptians and Babylonians, which was the determining the Situation of Places, or their Diſtance from the Equator, by obſerving *the Length of their longeſt and ſhorteſt Days*. And that this Obſervation might be performed with ſome Accuracy, they made uſe of a Species of perpendicular Sun-dials, having a Stilus or *Gnomon* erected upon a horizontal Plane, by which they were enabled to meaſure the Length or Shortneſs of the Shadow, in proportion to the Height of the Stilus.

It is difficult to ſay which of theſe two Nations are intitled to the Credit of this Invention. Herodotus * tells us, *that the Greeks firſt learned the Pole, the Gnomon, and the twelve Diviſions of the Day, from the Babylonians.* But in oppoſition to this it may be obſerved, that the Merit of this Invention of the Gnomon in Greece, is aſcribed by Pliny † and Diogenes Laertius, to the aſtronomical School of Miletus, and particularly to Anaximander and Anaximenes, the Diſciples of Thales; and there is reaſon to believe that this

* Herodotus, lib. 2. p. 145. Ed. H. Steph.

† Pliny, lib. 2. cap. 76. Umbrarum hanc rationem & quem vocant Gnomonicen invenit Anaximenes Mileſius Anaximandri Diſcipulus, primuſque Horologium, quod appellant Scioterican Lacedæmone oſtendit.

Method of Obſervation was well known to Thales himſelf. For though the actual Erection of a Gnomon was an Honour reſerved for one of his immediate Succeſſors, who placed at Lacedemon the firſt Sun-dial upon that Conſtruction that was ſeen in Greece *; yet it may be preſumed at the ſame time, that Thales, who had travelled into Egypt, where he learned both his Geometry and Aſtronomy, might bring from thence the Idea and Principle of this Inſtrument of Obſervation; for Diogenes Laertius particularly mentions, *That he was the firſt who found out the Paſſage of the Sun from Tropick to*

* Diogenes Laertius in Anaximandro, lib. 2. Ἔυρε δὲ καὶ γνώμονα πρῶτος, ἔκαὶ φησιν ἐπὶ τῶν σκιοθήρων ἐν Λακεδαίμονι τροπάς τε καὶ ἰσημερίας σημαίνοντα.

Tropick.

*Tropick**. But by what Inſtrument could this be determined unleſs by the Gnomon? For *the Aſtrolab* and *the Armillary Circles* are generally believed to have been invented by ſome of the later Greek Aſtronomers who flouriſhed under the Ptolemys; ſuch as Timocharis, Ariſtillus, or Eratoſthenes.

Thales is likewiſe ſaid to have been the Author of two Books, one *on the Tropick*, and one *on the Equinox*, the exact Times of which he probably determined by the Shadows of the Gnomon; and by this he was naturally led to another of his Diſcoveries, which was the Diviſion of the Year into *its four*

* Πρῶτος δὲ καὶ τὴν ἀπὸ τροπῆς ἐπὶ τροπὴν παρεδωκεν ἔτος. Diog. Laert. lib. 1. § 24.

Seaſons, which was a Conſequence of his finding the particular Days when the Sun appeared to be in the Tropics and in the Equinox.

His Diviſion of the Year into 365 Days, was undoubtedly brought by him from Egypt, as it is univerſally allowed * to have been an Egyptian Diſcovery prior to his Time, being aſcribed to the ſecond Mercury, ſirnamed Triſmegiſtus, who is ſuppoſed † to have lived about 50 Years after the Exodus, according to Euſebius. And Pliny

* Herodotus, lib. 2. p. 48. Macrobii Saturn. 1. 12. Strabo, lib. 17. p. 816.

† Euſebius in Chronico. Syncelli Chronograph. p. 123. Marſhami Chronicon ad Sæc. x. p. 245. Ed. Lipſ. 1676.

tells

tells us expreſsly, that the Diſcovery of this Length of the Year by the Addition of the five Days and a Quarter to the 360, was made by obſerving when *the Shadow returned to its Marks* *; which is a clear Proof that it was done by the Uſe of a Gnomon. And that the taking the Lengths of the Shadow, by way of Calculation, was an Idea familiar to Thales, appears from his firſt inventing the Method of determining the Height of the Pyramids

* Deinde Solis Meatum eſſe partium trecentarum, ſed *ut Obſervatio Umbrarum ejus redeat ad Notas*, quinos annis dies adjici, ſuperque quartam partem diei. Pliny, lib. 2. cap. 8. It is proper to obſerve here, that the odd Quarter of a Day, though known to the Egyptians, was not added till under the Reign of the Emperor Auguſtus, in the Year 25 before Chriſt.

by their Shadow, at that exact Inſtant of Time in the Day when the Shadow of a Man is found to be equal to his Height *.

It does not therefore ſeem to be an improbable Suppoſition, that this Method of obſerving by the Gnomon was originally imported from Egypt, where it was known long before this Dawn of the Greek Learning; for it has been the Opinion of ſeveral eminent Writers †, that their Pyramids and Obeliſks, which

* Diogenes Laertius in Thalete, lib. 1. § 27.

† Idemque inſinuant Obeliſci & Pyramides antiquiſſimæ, non ad Ornatum ſolum aut Pompam erectæ in Ægypto, ſed etiam ad captandam ope Umbrarum Altitudinem Solis. Riccioli Almageſt. Tom. 1. Præf. ix. Caſſini de l'Origine & du Progres de l'Aſtronomie, p. 13.

to

to common Travellers appeared to be Buildings merely of Ornament and Magnificence, were really Sun-dials upon a larger Scale, by which the Variation of the Length of the Shadow, in proportion to its Height, could be taken with a greater Degree of Accuracy. And to confirm this Opinion, it was found upon Examination by M. de Chazelles * in 1694, that the two Sides, both of the larger and ſmaller Pyramids, were placed exactly North and South, ſo as to be true meridian Lines even at this Day, and the other two Sides ſtood Eaſt and Weſt; which is a clear Proof that even in thoſe early Times in which they were built, they

* M. Fontenelle's Eloge de M. de Chazelles, dans les Mémoires de l'Academie pour 1710.

were

were ſo contrived by the Egyptians, to ſtand in the direction of the four cardinal Points of the Heavens for the Purpoſes of their aſtronomical Obſervations.

It is not my preſent Intention to regiſter all the particular Diſcoveries of *Aſtronomy*, but only to explain ſuch of them as are intimately connected with *the Progreſs of Geography*; for their Advances were ſo often made by the ſame Steps, that the one is not to be clearly underſtood without the other.

From the Days of Thales and his immediate Succeſſors, who flouriſhed in the Sixth Century before Chriſt, there ſeems to have been little done towards the ſolid Improvement of Geography

graphy for two hundred Years, till the Eſtabliſhment of the famous Aſtronomical School of Alexandria. For we have ſcarce any Fragments remaining of the School of Pythagoras; though at the ſame time it muſt be owned, that their having known the true Syſtem of the World by placing the Sun in the Center, and giving the Earth both the diurnal and annual Revolutions, are Proofs that their Knowledge of this muſt have been eſtabliſhed by clear and accurate Obſervations.

There is, however, an aſtronomical Obſervation mentioned during this Period, and it is indeed the firſt Greek one that is on Record, and is preſerved

to us by Ptolemy *, which is that of Meton and Euctemon, who obſerved the Summer Solſtice at Athens, during the Archonſhip of Apſeudes, upon the 21ſt of the Egyptian Month Phamenoth, in the Morning, being the 27th of June, 432 Years before Chriſt. This Obſervation was made with a View of determining the Beginning of their Cycle of XIX Years, which commenced upon the New Moon of the 15th of July immediately ſucceeding (being exactly 18 Days after the Solſtice), and fell, according to Diodorus †, upon the 13th of the Athenian Month Sciro-phorion.

* Mathem. Syntax. lib. 3. cap. 2. p. 62.

† Diodorus Siculus, lib. 12. p. 305.

This

This ſolſtitial Obſervation muſt have given Meton and Euctemon an Opportunity of determining the Latitude of Athens at the ſame time, had they but known the ſimple Manner of drawing the Concluſion; for as the Length of the Shadow of the Gnomon was narrowly watched at the Criſis of the Solſtice, the Proportion of that to the Height of the Gnomon was eaſily known, by which the Angle of the Sun's Altitude was given. And though the Sun's greateſt Declination was then very inaccurately known, being by ſome * ſuppoſed to be 24°, and by others † 23° 51′, which is only found at preſent to be 23° 28′ 10″, yet ſtill the Latitude of Athens might

* Strabo ad finem, lib. 2. & Vitruvius, lib. 9. cap. 8. & Meſſahala Arabs, lib. 2. Aſtrolabii, ex Indorum Obſervatione.

† Ptolemy, Math. Syntax. lib. 1. cap. 11. p. 18.

have

have been deduced within the Limitations of this Error; making at the ſame time Allowances for the groſs Manner in which Altitudes were determined without proper Inſtruments, and without the Solutions of Trigonometry, which appears to have been unknown till the Age of Hipparchus, by whom it was firſt introduced *.

It

* TRIGONOMETRY appears to have been firſt introduced by Hipparchus, according to Theon, in his Commentary on the Almageſt, lib. 1. cap. 9. p. 39. where treating upon *the Quantity of Right Lines in a Circle*, and having premiſed that Circles are ſuppoſed to be divided into 360 Parts, the Diameter into 120, and the Radius into 60, he adds the following Words:

" The Method of finding the Right Lines (or " Chords) in a Circle, is demonſtrated by Hip- " parchus in Twelve Books, and after him by Me- " nelaus

It would ſeem that Timocharis and Ariſtillus, who began to obſerve 295 Years

" nelaus in Six Books.—It is a thing much to
" be admired (continues, he) that this Man (viz.
" Hipparchus) with ſo little Difficulty, and by
" a few, and thoſe eaſy Theorems, has made the
" Diſcovery of their Quantities; and after this,
" by certain ſhort Lemmata, he demonſtrated
" a few, and thoſe the moſt uſeful of the
" Theorems, for obtaining the Quantities of
" theſe Right Lines; and then conſequentially,
" by theſe very Theorems, he has demonſtrated
" the Method of inveſtigating a Canon or
" Table, by which we may not only find from
" the Data, without any Inveſtigation, the
" Magnitudes laid down, but likewiſe by a
" linear Demonſtration we may inveſtigate
" them; ſo that if any graphical Error ſhould
" be introduced in the Numbers given by the
" Canon, we may with great Readineſs rectify
" them by means of the Projection."

Ptolemy

Years before Chriſt, were the firſt who introduced the Manner of determining the

Ptolemy, in his Almageſt, or Mathem. Syntax. lib. 1. cap. 9. has ſhewn us this Operation by finding the real Quantities of the Pentagons and other regular Figures inſcribed in a Circle, and from thence deduces his Method of calculating a Table of Subtenſes or Chords, to every 30′ of the Circle, which he ſubjoins to this Chapter.

But when they came to apply theſe to the Purpoſes of Trigonometry, their Manner of Calculation was very tedious by the *Subtenſes of double Arcs* inſtead of *Sines*, which was an After-Invention of the Arabians, appearing firſt in the Writings of Albategni, and their Caſes were ſolved by a Compoſition of Ratios betwixt ſix different Magnitudes, from which it was intitled, *The Canon of the ſix Quantities*, alluding to the three Sides and the three Angles contained in all Triangles

the Poſitions of the Stars, *according to their Longitudes and Latitudes*, taken with reſpect

Triangles whatever, both plain and ſpherical*.

In this embarraſſed State it continued till towards the Middle of the Tenth Century, when it was reduced by the Arabians to a clearer and more ſimple Method. For beſides the Introduction of Sines already mentioned, all the various Propoſitions were reduced to three plain Theorems by Geber ben Aphla, the Aſtronomer of Seville, and which are contained in his Preface to his Commentary on the Almageſt, which was publiſhed by Petreius of Norimberg in 1633.

There were two Caſes in ſpherical Triangles, however, to which theſe three Theorems did not extend; which are, when the three Sides are given, and the Angles required; or when the three

* Menelaus, lib. 3. Prop. 1. Ptolemy Almageſt. lib. 1. cap. 12. p. 18. & lib. 2. p. 35. Montucla's Hiſtoire de Mathematiques, Tome 1. p. 358.

reſpect to the Equator. This we know from Ptolemy, who has preſerved many of

three Angles are given and the Sides are required. And the Merit of the Solution of them was reſerved for Regiomontanus in the Middle of the Fifteenth Century. Trigonometry is alſo indebted to him, and his Maſter Purbachius, for having calculated a Table of Sines to every Degree and Minute of the Quadrant. It was upon this Occaſion, in 1464, that Regiomontanus is ſuppoſed to have introduced, for the firſt time, *Decimal Arithmetic* in his *Trigonometrical Canons*, in the Room of the *Sexageſimal Parts* which had formerly been in uſe; and this he did, as Wallis ſays, *ſilently* and *unobſerved*. See Wallis's Preface to his Algebra, and alſo p. 31. Regiomontanus likewiſe introduced the Uſe and Application of Tangents; and near 100 Years after this, about 1560, Rheticus added to theſe the Uſe of Secants in Trigonometry, and compoſed new Tables of Sines, Tangents, and Secants, calculated not only for Degrees and Minutes, but from ten Seconds to ten Seconds.

The

of their Obſervations in his Almageſt *; one in particular is well known,

The greateſt Addition, however, to this Branch of Mathematicks, was made by John Napier of Merchiſton, who introduced two new Theorems, which rendered the Solution of all the Caſes of ſpherical Triangles ſtill more eaſy and ſimple than they were before, by what are called *the Five Circular Parts.*

But whatever Reputation he might claim from that Diſcovery, *his Invention of Logarithms* in 1614, is ſtill much greater and more extenſive, and has ſpread its Influence to every Branch of mathematical Science. Though it muſt be confeſſed, that Trigonometry in particular received an infinite Advantage from it, by ſhortening the tedious Multiplication and Diviſion of natural Sines, which, beſides the Conſumption of ſo much Time, rendered the Calculations liable to frequent Errors.

* Ptolemy, Math. Syntax. lib. 7. cap. 2 & 3, p. 166, &c.

as it gave riſe to the famous Diſcovery of the Preceſſion of the Equinoxes; it was that of the Spica in Virgo, which Timocharis found to be 8° Weſt from the autumnal equinoctial Point, and likewiſe that it was one Degree and two Fifths to the North of the Equator: Both of which were found to be different by Hipparchus; ſo that this bright Star had ſhifted its Place with regard to theſe two Particulars in that Interval of Time elapſed betwixt theſe two Obſervations; for in one Caſe, he only found it to be 6° Weſt from the autumnal equinoctial Point; and in the other, that it was three Fifths of a Degree, or 36′ to the North of the Equator; but it was found, both by Timocharis and Hipparchus, to have remained nearly at the

Diſtance

Diſtance of two Degrees to the South of the Middle of the Zodiac or Ecliptic. From which it naturally appeared reaſonable for Hipparchus to ſuppoſe that the fixed Stars had a ſlow Motion round the Poles of the Zodiac: "Yet, as Ptolemy * tells us, "that though inclined to this Opi- "nion, yet Hipparchus ſays of him- "ſelf, "*That he heſitated in his own* "*Mind upon the Deciſion of the Queſtion,* "becauſe the Obſervations of Timo- "charis were not to be confidently "depended upon, as being made in a "rough and groſs Manner; and that

* Ptolemy Math. Syntax p. 168. Διςάζει δ' ὅμως καθάπερ καὶ αὐτὸς φησὶ, διὰ τὸ μήτε τας τηρήσεις τῶν περὶ τὸν Τιμόχαριν ἀξιοπίςως ἔιναι, παὺυ ὀλοσχερῶς ἐιλημμένας, μήτε τὴν ἐν τῳ μεταξύ χρόνῳ διαφορὰν ἱκανὴν ἤδη γινομένην πρὸς βεβαίαν κατάληψιν.

" the Interval of Time (though of 150
" Years and upwards) was not ſuffi-
" cient for a clear and certain Com-
" prehenſion of that Matter.

There was likewiſe an additional Reaſon for this Suſpenſion of Judgment in Hipparchus, which Ptolemy has preſerved in another Paſſage of his Almageſt*. For he tells us, that Hipparchus had found the greateſt Diſtance of the Spica of Virgo from the autumnal Equinox to be 6° 30′ in the 32d Year of the Third Calippick Period (viz. 146 before Chriſt) and that he found it to be only 5° 15′ in the 43d Year of the ſaid Period (viz. 135 before Chriſt); and as he could

* Mathem. Syntax. p. 61.

not

not apprehend that this Star ſhould make a Motion of 1° 15′ in 11 Years, he concluded that this Difference aroſe from ſome Inequality in the apparent Motion of the Sun: For though this Variation puzzled him, yet, ſays Ptolemy *, *He was prompted, from his Love of Truth, to conceal nothing which could tend in the leaſt Degree to carry any Perſons to a Suſpicion upon his Obſervations.* But by way of accounting for this, he was induced at one Time to ſuppoſe, that this Motion of the fixed Stars in varying their Diſtance from the equinoctial Point, was confined to ſuch of them as were near the Zodiac, as if this Irregularity was occaſioned by

* Βεβουλῆσθαι δὲ μόνον ὑπὸ φιλαληθείας, μὴ σιωπῆσαί τι τῶν ἰδίων εἰς ὑποψίαν ὁπωσδήποτε δυναμένων ἐνεγκεῖν.

the Sun, Moon, and Planets, which moved in this Path; and this Ptolemy calls *the firſt Hypotheſis of Hipparchus* *. But this he afterwards relinquiſhed, when he found that the Stars in the great Bear, and others which were at a conſiderable Diſtance from the Zodiac, ſhifted their Places equally with thoſe in the Zodiac, both with regard to the Equator and the equinoctial Colures.

From theſe Particulars, however, it ſufficiently appears, that Timocharis and Ariſtillus are intitled to a Share of the Merit of Hipparchus, who is ſo much celebrated for the Boldneſs of

* Ptolemy Mathem. Syntax. p. 164.

his

his Attempt in numbering the Stars, and ranging them all according to their Situations in the Heavens*. And it is likewiſe evident, that the Longitudes and Latitudes of the Stars were reckoned from the Equator both by Timocharis and Hipparchus; for it was only after the Preceſſion of the Equinoxes was fully eſtabliſhed by Ptolemy, that the Longitudes and Latitudes of the Stars were uniformly

* Hipparchus—auſus, rem etiam Deo improbam, annumerare poſteris Stellas, ac *Sidera ad normam expangere, organis excogitatis* per quæ *Singularum loca* atque magnitudines *ſignarent* ut facile diſcerni poſſet ex eo, non modo an obirent, naſcerenturve, ſed an omnino *aliqua tranſirent moverenturve*—cœlo in hæreditate cunctis relicto, ſi quiſquam qui rationem eam caperet, inventus eſt. Plinii Nat. Hiſt. lib. 2. cap. 26.

referred to the Ecliptic. It was then but an eaſy Tranſition of Thought in Hipparchus to aſſort and diſpoſe the different Parts of the Earth according to Latitude and Longitude, being only a new Application or Tranſpoſition of that Artifice which was already ſo happily introduced in the Arrangement of the Conſtellations, and therefore equally proper to be adopted in tracing the Meridians and Parallels of the Earth.

Strabo has preſerved the very Words of Hipparchus, in which he explains his Ideas upon this Subject, being a Fragment extracted from a Treatiſe of his wrote againſt Eratoſthenes.

" It

"It is impoſſible, ſays he*, either "for an illiterate Perſon, or a Man of "Learning, to acquire the neceſſary "Knowledge of Geography without "an Attention to the Heavens, and "to the Obſervations of Eclipſes. "For whether Alexandria in Egypt is "more Northerly than Babylon, or "more Southerly, or to what Diſtance "this amounts, cannot be determined "without conſidering them by their "Climates. In like manner, what "Places lie towards the Eaſt, or to-"wards the Weſt; and whether more "or leſs, no Perſon can know ac-"curately without comparing the "Eclipſes of the Sun and Moon." Thus far Hipparchus.

* Strabo, lib. 1. p. 7.

As the two Diſtinctions here pointed out give us the clear Ideas of Latitude and Longitude, it is with great Juſtice that Hipparchus is univerſally allowed to have fixed the firſt ſolid Foundation of Geography by uniting it to Aſtronomy, and ſo rendering its Principles ſelf-evident and invariable *.

Pliny † likewiſe confirms this, when, after mentioning Thales and Sulpicius Gallus,

* See likewiſe what Strabo ſays of Hipparchus, lib. 2. p. 131, 2. Ἀνέγραψε γαρ, ὡς αὐτός φησι, τὰς γινομένας ἐν τοις οὐρανίοις διαφορας καθ' ἑκασον τῆς γῆς τόπον των ἐν τῇ καθ' ἡμᾶς τεταρτημορίων τεταγμένων, λέγω δὲ τὸν ἀπο τῦ ἰσημερινου μέχρι τῦ βορείυ πόλυ.

† Utriuſque Sideris curſum in ſexcentos annos præcinuit Hipparchus, menſes gentium, dieſque & horas, *ac ſitus locorum* & viſus populorum complexus, ævo teſte, haud alio modo quàm

Gallus, who had both predicted Eclipſes, he adds, *that Hipparchus had foretold the Revolution* (of the Eclipſes) *of the Sun and Moon for* 600 *Years, comprehending the Months, Days and Hours of different Nations, and the Situation of Places.* By which it would ſeem, that the Latitudes and Longitudes of theſe Places were particularly given.

But the fulleſt and ſtrongeſt Authority for appropriating this Invention to Hipparchus, is that of Ptolemy in his Geography, lib. 1. cap. 4. who ſays, " That Hipparchus was the only Au- " thor who had given *the Elevations of* " *the North Pole of a few Cities*, in pro-

quàm Conſiliorum Naturæ particeps. Plinii Nat. Hiſt. lib. 2. cap. 12.

" portion to the great Number that
" were to be delineated, and ſuch too,
" as lay under the ſame Parallels.
" Some that came after Hipparchus
" had given thoſe of other Places that
" lay upon the ſame Meridian, be-
" cauſe their moſt favourable Voyages
" were commonly from North to
" South; but that moſt of the Di-
" ſtances, and principally thoſe to-
" wards the Eaſt and Weſt, were laid
" down in a ſtill groſſer Manner;
" not from any Negligence of thoſe
" who recorded them, but becauſe
" they had no ready Method of
" bringing them to a mathematical
" Exactneſs; and likewiſe, becauſe
" there were not many Eclipſes of the
" Moon which had been obſerved at
" different Places at the ſame Inſtant

" of

" of Time: For it is upon Record,
" that an Eclipſe, which was obſerved
" at Arbela at Five o'Clock, was
" ſeen at Carthage only at Two
" o'Clock; from which it clearly ap-
" peared, what was the Diſtance of
" theſe two Places towards the Eaſt
" and Weſt given in equinoctial
" Time."

It is however a little remarkable, that though Latitudes and Longitudes were in this Manner introduced and pointed out by Hipparchus, yet ſo little were they attended to till the Days of Ptolemy, that none of the intermediate Authors, ſuch as *Strabo* *, *Vitruvius*, and

* Strabo, lib. 2. p. 132. makes indeed an Apology for his not having done it, as if the

and *Pliny*, who all of them entered into a minute Deſcription of the Geographical Situation of Places according to the Length and Shadows of the Gnomon, have ever given us the leaſt Hint of the Latitude or Longitude of any one Place whatever in the Language of Degrees and Minutes. So common is it in Science to ſee the Seeds of great and uſeful Diſcoveries often lie dormant and neglected for many Years, till there ariſes ſome Man of Abilities equal to the firſt Inventor, who ſepa-

giving of theſe Obſervations *(which determine Latitudes and Longitudes)* was neither the Buſineſs of a Geographer nor a Politician, and that they were beſides full of Perplexity; *adding*, that it was ſufficient for him to propound from Hipparchus other Things that were more diſtinguiſhable and more ſimple.

rates

rates them, by an original Spirit of Diſcernment, from the Maſs of Matters otherwiſe of ſmaller Importance, reſtores them to their true Point of Light, and often improves them beyond the Ideas with which they were repreſented in the firſt Conception.

When the true Principles of Geography were thus pointed out by this new Invention of Latitude and Longitude, it was no Wonder that Maps were from thence made to aſſume a new Form of Projection eſſentially different from thoſe in uſe prior to this Period. It was for this Purpoſe that the Planiſphere, or the Delineation of the Sphere in Plano, is ſaid

by

by Syneſius * to have been introduced by Hipparchus, *in order to preſerve the Sameneſs of the Proportions in the Diverſity of the Figure.* It muſt be owned, however, that the previous Steps to this new Projection of the Sphere, had been in a great Meaſure made eaſy by Archimedes, when he invented (at leaſt 50 Years and upwards before Hipparchus) thoſe noble Theorems of his for meaſuring the Surface of a Sphere and its different Segments; which were none of the leaſt important Diſcoveries of that great Geometrician.

* Syneſius de dono Aſtrolabii, p. 310. Σφαιρικῆς ἐπιφανείας ἐξάπλωσιν, ταυτότητα λόγων ἐν ἑτερότητι τῶν σχημάτων τηρῦσαι. ἠνίξατο μεν, Ἱππαρχος, &c.

We find in Strabo † an Alluſion to a ſpherical Projection in Plano, where the Meridians bended towards each other, ſo as to make the Figure of a Cone.

For the Maps that were on Record before the Time of Hipparchus, were little more than rude Outlines and topographical Sketches of different Countries; excepting the ſingle Map of Eratoſthenes, which I ſhall explain more particularly, after having given a ſhort Account of thoſe that went before it.

The earlieſt were thoſe of Seſoſtris, mentioned by Euſtathius in his Epiſtle

† Strabo. Geogr. lib. 2. p. 117. Ἐν τῳ ὑπτιῳ γε ὑ διοίσει πίνακι τας ἰυθειας μικρον συνιυσας ποιειν κωνοιτας μεσημβριτας.

pre-

prefixed to his Commentary on Dionyſius's Περιήγησις, who ſays, "that this "Egyptian King, having traverſed "great Part of the Earth, recorded "his March in Maps, and gave "Copies of his Maps not only to the "Egyptians, but to the Scythians, "to their great Aſtoniſhment *."

The Jews ſeem to have had Surveyors among them; and ſome have imagined from this, that they had made a Map of the Holy Land when they gave the different Portions to the Nine Tribes at Shilo, as mentioned in Joſhua, Chap. xviii. ver. 4. 8. and 9. For they are there ſent to walk through

* Και Σεσωτρις δε, φασὶν, ὁ Αἰγύπτιος πολλὴν περιεληλυθὼς γῆν πιναξί τε δέδωκε τὴν περίοδον, &c. p. 6. Ed. H. Steph.

the

the Land, and to deſcribe it; and they are afterwards ſaid *to have deſcribed it in Seven Parts in a Book.* And Joſephus tells us, that when Joſhua ſent out People from the different Tribes to meaſure the Land, he gave them as Companions Perſons well inſtructed in Geometry, who could not be miſtaken in the Truth from their Skill *.

He afterwards mentions, that the Men who were ſent, being Ten in Number, περιοδεύσαντες τε καὶ τιμησάμενοι τὴν γῆν, *going round and eſtimating the Land,* returned in the ſeventh Month to Joſhua at Shilo.

* Καὶ ἄνδρας τοὺς ἐκμετρησομένους τὴν χώραν αὐτῶν ἐξέπεμψε, παραδοὺς αὐτοῖς τινὰς γεωμετρίας ἐπιστήμονας οὓς ταλησὶς οὐκ ἤμελλε λήσεσθαι διὰ τὴν τέχνην. Joſephus, lib. v. cap. 1. p. 141.

From

From this, therefore, we may reaſonably preſume, that a geometrical Survey was then made of the Holy Land; though it does not fully determine whether their Menſuration was only taken down in Numbers, or regularly projected and digeſted into a Map.

The firſt Grecian Map on record was that of Anaximander, mentioned by Strabo, lib. 1. p. 7. It has been conjectured by ſome, that this was a general Map of the then known World, and is imagined to be the one referred to by Hipparchus under the Deſignation of *the Ancient Map**, which he in a few Particulars preferred to that of Eratoſthenes; and ſome con-

* Αρχαιας πινακας. Strabo, lib. 2. p. 69.

jectured,

jectured, that Anaximander, "by in-"venting a Sphere, and introducing "a Map, and a Meaſure of the Cir-"cumference of the Sea and Land," according to Diogenes Laertius, may be * ſuppoſed † to be one of the Mathematians alluded to by Ariſtotle at the End of his Second Book De Cœlo ‡, who made *the Circumference of the Earth* to be 400,000 Stadia, being the firſt groſs

* Και γῆς και θαλασσης περιμέτρον πρῶτος ἐγραψεν. Lib. 2. § 2.

† Snellius in his Eratoſthenes Batavus, lib. 1. p. 22.

‡ Καὶ των Μαθημαλικων ὅσοι τὸ μέγεθος ἀναλογίζεσθαι πειρωνται της περιφερείας, εἰς τετρακοσια λέγουσιν εἶναι μυριαδας σταδίων. Ariſtoteles, vol. 1. p. 472. Ed. Du Val. This however may be an Argument againſt that Work being wrote by Ariſtotle, as Eratoſthenes was generally allowed to have been the firſt who attempted that Menſuration.

groſs Calculation that was attempted to be given of that *great Problem in Geography.*

The Map of Ariſtagoras, Tyrant of Miletus, is likewiſe particularly worthy of our Attention, becauſe it is ſo minutely deſcribed by Herodotus *, and will give us ſome Idea of the Nature of the Maps in thoſe early Ages. He tells us, that Ariſtagoras ſhewed it to Cleomenes King of Sparta, with a View of inducing him to attack the King of Perſia even in his Palace at Suſa, in order to reſtore the Ionians to their ancient Freedom. It was traced upon Braſs or Copper, and contained the intermediate Coun-

* Herodotus, Lib. 5. p. 347.

tries

tries which were to be traverſed in that March. The Words of Herodotus* muſt not however be interpreted too literally, as if it contained "the whole Circumference of the "Earth, the whole Sea or Ocean, "and all the Rivers." For notwithſtanding the Pompouſneſs of the Expreſſion, it may fairly be concluded, from the State of Geography at that Time, that *the Sea* meant only the Mediterranean, and therefore *the Earth* or Land, the Coaſts of that Sea, and more particularly the Leſſer Aſia extended towards the Middle of Perſia, and *the Rivers* were the Halys, the Euphrates, and the Tigris, which Herodotus men-

* Ἔχων χάλκεον πίνακα, ἐν τῷ γῆς ἁπάσης περίοδος ἐτετμήκει, καὶ θάλασσά τε πᾶσα καὶ πόταμοὶ πάντες.

tions

tions as neceſſary to be croſſed in that Expedition. It contained one ſtraight Line, called the Royal Highway, ὁδὸς ἡ Βασιλήϊη, taking in all the Stations or Places of Encampment, which were called σαθμοι, from Sardis to Suſa; ſo that it was an Itinerary, or what the Greeks diſtinguiſhed by the Title of ἀπογραφη σαθμων *. There were 111 of theſe Stations in the whole Extent of this Line or Road, containing 13,500 Stadia, or 450 Paraſangæ, which being reduced to the Roman Mile, allowing Eight Stadia to each Mile, amounts to 1687 and

* Strabo, Lib. 2. p. 69. Xenophon has given us the March of the younger Cyrus's Army through theſe very σαθμοι, and their different Diſtances in Paraſangæ in his Ανάβασις, Lib. 1.

One-

One-half Roman Miles; and as it was a March of Ninety Days, Herodotus tells us, that 150 Stadia were allowed for a Day's March, which brings it to Eighteen Roman Miles and Three-fourths for each Day. If we would accommodate this to the Engliſh Statute Mile, which contains 5280 Feet, whereas the Roman Mile conſiſted only of 5000 Feet, it will reduce a Day's March to Eighteen Engliſh Statute Miles and One-ſixth of a Mile nearly, as the Roman Itinerary Foot differed very little from the preſent Engliſh Foot, as appears from two Itinerary Diſtances which have been meaſured; one is the Twenty-five Miles from Bologna to Modena, taken by Ricciolus; and the other, the Twenty-one Miles betwixt London

don and Verulam, found by ſome Surveyors, quoted by Bernard, to contain 20.37 Miles, of 500 Engliſh Feet to a Mile *.

Theſe Itinerary Maps of the Places of Encampment, were indiſpenſably neceſſary in all Armies. We find Athenæus, in his Deipnoſoph. Lib. 10. p. 442. quotes Bæton as Author of a Work, intituled σαθμοι της Αλεξανδρε πορειας, *The Encampments of Alexander's March*; and he likewiſe cites Amyntas, εν τοις σαθμοις. And Pliny †, Lib. 6.

* Dr. Murdoch's Enquiries and Conjectures concerning Meaſures of Length prefixed to Buſching's Geography, Vol. 1. p. 23. Bernardus de Menſuris Antiquis, p. 230, &c.

† Verùm ut terrena demonſtratio intelligatur, Alexandri magni veſtigiis inſiſtamus, Diognetus & Bæton ejus menſores ſcripſere, &c. Epiſtolæ quoque Regis ipſius conſentiunt.

cap. 17. tells us, that Diognetus and Bœton were the Surveyors of his Marches; he then quotes the exact Number of Miles according to their Menſuration, and afterwards confirms it by referring to the Letters of Alexander himſelf. It likewiſe appears from Strabo *, that Alexander was very careful in perſonally examining the Meaſures of his Surveyors †, having

* Strabo, lib. 2. p. 69.

† There is a Difficulty occurs with regard to the Meaſures of theſe Surveyors of Alexander, becauſe Pliny has given the Diſtances of Places as delivered by them in *the Roman Millia Paſſuum*, a Menſuration unknown to them, and not in the Greek Stadia. Dodwell had obſerved this with regard to the Voyages and Diſtances of Nearchus and Oneſicritus, who were Alexander's Admirals; and he ſup-

 poſes

having his Deſcriptions always from the moſt ſkilful in every Country. And the ſame Author acquaints us, that a Copy of this great Monarch's Survey was given by Xenocles his

poſes that Pliny took the Reduction of theſe Diſtances from Juba, who had abridged their Writings, as alluded to in Pliny, lib. 6. cap. 23. and therefore Juba might perhaps have done the ſame to the Writings of Bœton and Diognetus; though this is not quite conſiſtent with a Paſſage of his, lib. 6. cap. 17. where, after having given their Menſurations in Roman Miles, he adds, *in quibuſdam Exemplaribus diverſi Numeri reperiuntur*, as if he had been conſulting different Manuſcripts of the original Writings of theſe Authors. See Dodwell's Diſſertatio de Nearcho in Hudſon's Geogr. Minor, vol. 1. p. 132. But as Pliny gives likewiſe the Meaſures of Eratoſthenes and other Greek Writers in Roman Miles, it is more probable to ſuppoſe they were Reductions made by himſelf. Pliny, lib. 6. paſſim.

Treaſurer

Treaſurer to Patrocles the Geographer, who, as Pliny informs us, was Admiral of the Fleets of Seleucus and Antiochus. His Book on Geography is often quoted both by Strabo and Pliny; and it appears that this Author furniſhed Eratoſthenes with the principal Materials and Authorities for conſtructing the oriental Part of his Map of the then known World. For the Voyages of Patrocles under Seleucus upon the Caſpian Sea and elſewhere, were a kind of Supplement to thoſe Meaſurements given by Bœton and Diognetus already mentioned, and by Nearchus and Oneſicritus, the two Admirals who were employed under Alexander, and therefore Pliny * quotes

* Reliqua inde Seleuco Nicatori peragrata ſunt. Pliny, lib. 6. cap. 17.

them immediately after. It appears likewiſe from the ſame Paſſage, that Megaſthenes and Dionyſius were two Surveyors ſent into India by Ptolemy Philadelphus for the Purpoſes of Geography, and their Authority was ſometimes ſet in oppoſition to Patrocles by Hipparchus, in his Criticiſm upon Eratoſthenes's Geography *.

I have dwelt a little the longer upon theſe different Surveys which took their Riſe from Alexander's Expedition and Conqueſts and thoſe of his immediate Succeſſors, becauſe Geography began to aſſume a new Face and Form from this memorable Æra. For Eratoſthenes, who is deſervedly conſidered as the great Father of Chronology,

* Strabo, lib. 2. paſſim.

employed

employed his eminent Abilities and Learning with equal Succeſs to reduce Geography into a regular Syſtem, and laid its Foundation upon clear and ſolid Principles.

We muſt do him the Juſtice to allow, that it was he that firſt introduced into his Map *a regular Parallel of Latitude* *. It was a geographical Outline traced over certain Places whoſe longeſt Day was obſerved to be exactly of the ſame Length. He begun it from the Straits of Gibraltar, and it thence paſſed through the Sicilian Sea, and near the ſouthern Extremities of Peloponneſus, and was continued through the Iſland of Rhodes and the Bay of Iſſus, and there entering Cilicia,

* Strabo, lib. 2. initio, p. 67.

and ſo croſſing the Euphrates and Tigris, was extended to the Mountains of India. By means of this Line he endeavoured to rectify the Errors in the ancient geographical Map, ſuppoſed to be that of Anaximander. In drawing this Parallel, he was regulated by obſerving where the longeſt Day conſiſted of fourteen Hours and a Half, which Hipparchus afterwards determined to be the Latitude of 36°, making by this a ſort of Tranſlation of it into his own aſtronomical Language.

This firſt Parallel through Rhodes, was ever afterwards conſidered with a Degree of Preference like the Foundation Stone of all the ancient Maps; for it was traced through the Middle of the Mediter-

Mediterranean, whoſe Coaſts were in the Center of the principal Nations of Antiquity, and the Longitude of the then known World was often attempted to be meaſured in Stadia and Miles, according to the Extent of that Line, by many ſucceeding Geographers. The running of this Parallel was ſo happy a Thought in Eratoſthenes, that it not only encouraged him to trace upon his Map other Parallels at certain Intervals from his firſt, ſuch as one through *Alexandria*, another through *Syene*, and another through *Meroe*, but he undertook to trace at Right Angles to theſe *a Meridian* paſſing through Rhodes and Alexandria down to Syene and Meroe. And as the Progreſs he thus made tended naturally to enlarge his Ideas upon this Science, he at-

tempted a ſtill more arduous Taſk, which was *to determine the Circumference of the Globe* by an actual Meaſurement of a Segment of one of its great Circles, making his Computation upon the whole, by uniting certain accurate Obſervations made in the Heavens, with a correſponding Diſtance carefully ſurveyed and taken upon a Meridian of the Earth.

The Segment of the Meridian which he fixed upon for this Purpoſe, was that between Alexandria and Syene *,

* Cleomedes, lib. 1. p. 53. Martianus Capella, lib. 6. p. 194. tells us, that it was *meaſured by Ptolemy's Surveyors*, per menſores Regios Ptolemæi, though he ſeems to have made a Miſtake in ſaying that the Diſtance was betwixt Syene and Meroe, inſtead of betwixt Alexandria and Syene.

the

the Diſtance of which was meaſured, and found to be 5000 Stadia, and the Angle of the Shadow upon the Scaphia or Sun-dial, which was obſerved at Alexandria, was equal to the 50th Part of the Circle; for at Syene there was no Shadow from the Gnomon at the Mid-day of the Summer Solſtice; and that this might be more accurately taken, they dug a deep Well, which being perpendicular, was completely illuminated at the Bottom when the Sun was vertical *. Though this even was not fully ſufficient to give the exact Line of the Tropic, becauſe the Sun was found to be vertical, or to caſt no

* Pliny, lib. 2. cap. 73. and lib. 6. cap. 29. Servius ad Eclog. 3. Virgil. Strabo, lib. 17. p. 817.

Shadow at all for a circular Space of 300 Stadia, becauſe * the Sun's Diameter being equal to 32 Minutes, would therefore appear perpendicular at the ſame Inſtant of Time to an Extent of Ground correſponding to that Number of Minutes; and therefore Ricciolus concludes, that this vertical Obſervation muſt have extended 150 Stadia on each Side of Syene †.

The Subſtance of this Account is taken from Cleomedes, who ſeems to have extracted it literally from Eratoſthenes's original Work, intituled Μετρησεις ‡, and it is publiſhed as ſuch

* Ἆσι οἱ γίνεσθαι—καὶ τοῦτο γίνεσθαι, λόγος, ἐπὶ σταδίους τριακοσίους τὴν διάμετρον. Cleomedes, lib. 1. p. 53.

† Almageſt. vol. 1. lib. 3. cap. 27. p. 163.

‡ Fabricii Biblioth. Græc. vol. 2. p. 477.

at

at the End of the Oxford Edition of Aratus in 1672, though under the Title of Μετρον της γης περιφερειας. By this Account Eratoſthenes made the Circumference of the Earth amount only to 250,000 Stadia, whereas a Cloud of original Authors * have uniformly given the Numbers to be 252,000. And to reconcile theſe two, Dr. Murdoch † has ingenioufly ſuppoſed, that inſtead of 7° 12′, the Difference of Latitude was 7° 8 $\frac{1}{2}$′, which

* Strabo, lib. 2. p. 132. Geminus apud Petav. Uranol. p. 51. Vitruvius, lib. 1. cap. 6. Macrobius, lib. 1. cap. 20. Pliny, lib. 2. cap. 108. Capella, lib. 6. c. 1. Cenſorinus de die natali, cap. 2.

† Dr. Murdoch's Enquiries concerning Meaſures of Length, prefixed to Buſching's Geogr. vol. 1. p. 27.

was the $\frac{1}{50}$ $\frac{2^{th}}{5}$ of the Circumference, which would bring the Calculation to 252,000 Stadia, and that Cleomedes neglected the ſmall fractional Part of the Denominator; but that the principal Miſtake was in meaſuring the Diſtance, and finding it to be 5000 Stadia. Indeed nothing is more common than to find a Confuſion of Numbers in the Diſtances given us by ancient Authors; for though theſe 5000 Stadia are mentioned as the Diſtance betwixt Alexandria and Syene by ſo many Authors, yet we know that Marinus and Ptolemy * did not allow

* Ptolemy. Geogr. lib. 1. cap. 11. Καὶ ἔτι τὸ τὴν μὲν μίαν μοίραν οἵων ἐστὶν ὁ μέγιστος κύκλος μοιρῶν τ ξ πεντακοσίους ἐπὶ τῆς ἐπιφανείας τῆς γῆς ἀπολαμβάνειν σταδίους, ὅτι ταῖς ὁμολογουμέναις ἀναμέτρησεσι σύμφωνον ἐστι.

above

above 3600 Stadia to that Diſtance, as the 7° 12′ amounted exactly to that Number upon the Proportion of 500 Stadia to a Degree, which Ptolemy tells us, *was agreeable to Menſurations that were allowed and acknowledged.* The ſame Number of 5000 Stadia is ſaid to have been the Diſtance ſuppoſed by Poſidonius betwixt Rhodes and Alexandria *, where he had concluded that the Segment of the Meridian was the 48th Part of a great Circle from an Obſervation of the Star Canopus; whereas Strabo † tells us, that the Seamen only allowed it to

* Cleomedes, lib. 1. p. 51.

† Strabo, lib. 1. p. 25. & lib. 2. p. 125. Pliny, lib. 5. cap. 31. Rhodus—diſtat ab Alexandria, ut Eratoſthenes, ccccLxix mill.=3752 Stadia.

be

be a Diſtance of 4000 Stadia, and that Eratoſthenes, by his gnomonical Obſervations, concluded it to be only 3750. In like manner Pliny * tells us that it was 5000 Stadia betwixt Syene and Meroe; but in another Paſſage †, after mentioning the various Meaſures of Eratoſthenes, Artemidorus and Seboſus, who differed from each other, he adds, *that the Diſputes upon that Head had been lately determined by Surveyors ſent thither by Nero, who found it to meaſure* 862 *Miles*; though from the intermediate Diſtance there ſpecified, it appears that the collected Numbers give 874, and by multiplying each of theſe by 8, to increaſe them

* Lib. 2. cap. 73.

† Pliny, lib. 6. cap. 29.

to

to Stadia, will give in the firſt 6896 Stadia, and in the ſecond 6992, both of which differ very materially from 5000 Stadia.

The Inveſtigation of this Problem of the Circumference of the Earth, was eſſentially neceſſary for determining the radical Principles of all Maps, and therefore the moſt eminent of the ancient aſtronomical Geographers made repeated Endeavours to obtain an Accuracy in this Calculation. Eratoſthenes, by making the Circumference as I have already mentioned to be 252,000 Stadia, allowed therefore 700 Stadia to a Degree; which, by the Reduction of 8 Stadia to a Roman

man Mile of 5000 Feet, amounted to 87 ½ Roman Miles to each Degree.

Hipparchus added 25,000 Stadia to this Meaſure of Eratoſthenes, according to Pliny, lib. 2. cap. 108, though the Obſervation is not mentioned from which this Concluſion is drawn, which it were to be wiſhed Pliny had done, as it increaſes the Error of Eratoſthenes. This Addition however makes the Circumference to conſiſt of 277,000 Stadia, which was an Allowance of 769 Stadia, or 96 Roman Miles to each Degree *.

* It would ſeem from two Paſſages of Strabo, lib. 2. p. 113, & p. 132, as if Hipparchus admitted the Menſuration of Eratoſthenes.

Poſ-

Poſſidonius, in like manner, computed the Circumference of the Earth to be 240,000 Stadia, by multiplying 5000 (the ſuppoſed Diſtance betwixt Rhodes and Alexandria) by 48, the Segment of the Meridian according to his Obſervation betwixt theſe two Places; but Cleomedes, when he mentions this Concluſion, he adds, *if the Diſtance is* 5000, *but if not, in proportion to the Diſtance* *: And as Eratoſthenes had made the Diſtance to be only 3750 Stadia, and Poſſidonius reſting his Concluſion upon the Deduction from his aſtronomical Obſervation of the Arch of the Meridian, it was natural for him to infer, that if

* Cleomedes, lib. 1. p. 52. Ἐὰν ὦσιν αἱ ἀπὸ Ῥόδου μυριακισχίλιοι· εἰ δὲ μή, κατὰ λόγον τῦ διαστήματος.

he

he admitted the Diſtance given by Eratoſthenes to be true, being taken upwards of 170 Years before his Time, upon that Hypotheſis, the Circumference of the Earth would be only 180,000 Stadia, as 3750 multiplied by 48 will produce that Number; and indeed Strabo * tells us, that this very Calculation was approved of by Poſſidonius. It is for this Reaſon that he is quoted † as having had two Opinions upon the Quantity of the Circumference of the Earth, and that he was therefore the firſt Geographer who advanced the Opinion of allowing

* Strabo, lib. 2. p. 95. διὰ τὸ Ποσειδώνιον ἐγκρῖναι περὶ ὀκτὼ καὶ δέκα μυριάδας ὕσαι.

† Snellii Eratoſthenes Batavus, lib. 1. cap. 16. p. 88. & Riccioli Geogr. lib. 5. cap. 8. p. 144.

only

only 500 Stadia to a Degree, which was afterwards adopted by Marinus and Ptolemy *. By the firſt Hypotheſis, therefore, there would be 666 Stadia, or 83 Roman Miles to a Degree; and by the ſecond, 500 Stadia, or 62½ Roman Miles.

The Diſcoveries and Improvements of Eratoſthenes as a Geographer, have naturally led me to explain theſe various Menſurations and Calculations of the Circumference of the Earth, which indeed materially affected the Dimenſions of all the ancient Maps. It is proper however to obſerve, that his Map appears to have contained little more than the States of Greece, and the Dominions of the Succeſſors of

* Ptolemy Geogr. lib. 1. cap. 11.

Alexander,

Alexander, digeſted from thoſe Surveys already mentioned. He had ſeen indeed, and has quoted, the Voyages of Pytheas into the great Atlantic Ocean, which gave him ſome faint Idea of the Weſtern Parts of Europe; but withal ſo imperfect, that they could not be realiſed into the Outline of a Chart. Strabo * tells us, that he was extremely ignorant of Spain, Gaul, Germany and Britain, as well as of the Geti and Baſtarni; he was equally ignorant of Italy, the Coaſts of the Adriatic, of Pontus, and of all the Countries towards the North. And he mentions in another Paſſage, that Eratoſthenes had made the Diſtance from Epidamnus, or Dyrrachium, on

* Strabo, lib. 2. p. 93.

the

the Adriatick, to the Bay of Thermæ on the Ægean Sea, quite acroſs Epirus, to be only 900 Stadia, when it was really above 2000 Stadia; and in another Inſtance, he had enlarged the Diſtance from Carthage to Alexandria to be 15,000 Stadia, whereas it amounted to no more than 9000 Stadia *.

This was therefore the State of Geography, and the Nature of the Maps, prior to the Diſcoveries of Hipparchus, who, like an abler Architect, introduced a new Plan of Building more certain in its Principles and more ſimple in its Conſtruction, and where they might employ without

* Strabo, lib. 2. p. 92.

waſte

waſte all the better Parts of the ancient Materials. His Additions tended to make a new and cloſer Union betwixt Aſtronomy and Geography, from which they derived mutual Advantages, and widened their Bottom for the Acceſſion of new Improvements.

It appears that War has been generally the Occaſion of the moſt accurate Maps of different Countries, and therefore Geography, about this Æra, began to make conſiderable Advances from the Progreſs of the Roman Arms. For that great People, as they were *the Conquerors*, ſo they became *the Surveyors* of the World. In all the Provinces they occupied, we find that

Camps were every where conſtructed at proper Intervals, and Roads were raiſed with ſubſtantial Materials for an eaſy Communication between theſe different Places of Encampment; ſo that *Civilization* and *Surveying* were carried on *according to Syſtem* through the Extent of that large Empire. Every new War produced a new Survey and Itinerary of the Countries where the Scenes of Action paſſed; ſo that the Materials of Geography were accumulated by every additional Conqueſt. Polybius *, when he tells us, that at the Beginning of *the ſecond Punic War*, Hannibal was preparing his Expedition againſt Rome, by croſſing from

* Polybii Hiſtoria, lib. 3. p. 193. Ed. Caſaub. Paris 1609.

Africa

Africa into Spain, and ſo through Gaul into Italy, he ſays, *that all theſe Places were meaſured or ſurveyed with the utmoſt Care by the Romans.*

Without entering into the minuter Execution of the Surveys of particular Provinces with which every Roman General was regularly furniſhed before his March, and which Vegetius has well deſcribed *, I ſhall only add a remark-

* Primum itineraria omnia regionum, in quibus bellum geritur, pleniſſimè debere habere perſcripta: ita ut locorum intervalla non ſolum paſſuum numero, ſed etiam viarum qualitates perdiſcat: compendia, diverticula montes, flumina, ad fidem deſcripta, confideret: uſque eo, ut ſolertiores duces *itinera* provinciarum, in quibus neceſſitas geritur, non tantum *adnotata*, ſed etiam *picta*, habuiſſe firmentur, ut non ſolum conſilia

a remarkable Fact preſerved to us by Æthicus in the Preface to his Coſmographia. We are there informed, that Julius Cæſar ordered *a general Survey to be made of the whole Roman Empire* by a Decree of the Senate; the Surveyors are ſaid to have been Men of great Wiſdom, and inſtructed in every Branch of Philoſophy. The three Surveyors were Zenodoxus, Theodotus, and Polyclitus, and were each of them appointed to ſurvey a different Diviſion of the Empire. It began in the Conſulſhip of Julius Cæſar and Marc Antony (before Chriſt 44), and continued for 25 Years one Month and ten Days, to the Con-

conſilia mentis, verum adſpectu oculorum, viam profecturis, eligerent. Vegetius De Re Militari, lib. 3. cap. 6.

ſulſhip of Sentius Saturninus and Lucretius Cinna (before Chriſt 19). The Eaſtern Part of the Empire was aſſigned to Zenodoxus, who finiſhed it in 14 Years five Months and nine Days, being in the Conſulſhip of Auguſtus IV. and Craſſus (before Chriſt 30). The Northern Part was completed by Theodotus in 20 Years eight Months and ten Days, in the Conſulſhip of Auguſtus X. (and Flaccus) (before Chriſt 24). And the Southern Part was finiſhed by Polyclitus in 25 Years one Month and ten Days *.

As

* Itaque Julius Cæſar, biſſextilis rationis Inventor, divinis humaniſque rebus ſingulariter inſtructus, cum conſulatus ſui faſces erigeret, ex Senatus-conſulto cenſuit omnem orbem jam Romani

As the different Spaces of Time taken up in each Survey are regiſtered

Romani nominis admetiri per prudentiſſimos viros & omni Philoſophiæ munere decoratos. Ergo a Julio Cæſare & M. Antonio Coſſ. orbis terrarum metiri cæpit, id eſt, a conſulatu ſuprafcripti uſque ad conſulatum Auguſti *tertium* (lege *quartum*) & Craſſi, annis xxi. (lege xiv.) menſibus v. diebus ix. Zenodoxo omnis oriens dimenſus eſt, ſicut inferius demonſtratur. A Conſulatu item Julii Cæſaris & M. Antonii uſque in Conſulatum Auguſti decimum, annis xxix. (lege xx.) menſibus viii. diebus x. a Theodoto ſeptentrionalis pars dimenſa eſt, ut evidenter oſtenditur. A Conſulatu ſimiliter Julii Cæſaris uſque in Conſulatum Saturni & Cinnæ a Polyclito meridiana pars dimenſa eſt, annis xxxii. (lege xxv.) menſe i. diebus x. ſicut definita monſtratur. Ac ſic omnis orbis terræ intra annos xxxii. (lege xxv.) a dimenſoribus peragratus eſt, & de omni ejus continentia perlatum eſt ad Senatum. Æthici Coſmographia, p. 107. Ed. H. Stephani, 1577.

according to the Conſulſhips, I have corrected the Numbers in the Manner done by Weſſelingus in his Preface to the Itinerary of Antoninus, which indeed is ſo directly pointed out by the *Faſti Conſulares*, that there can be no Doubt of the true Reading. The only Difficulty with regard to the Authenticity of the Fact, ariſes from the Silence of Pliny, who has made no Mention of theſe three Surveyors, and of the important Taſk they had executed, which one ſhould have expected in a Roman Author who otherwiſe ſo minutely mentions the Diſtances taken by the Surveyors of Alexander upon a leſs intereſting Tract of Country. But perhaps we ought to ſuppoſe that this was *the general Survey aſcribed to Marcus Vipſanius*

ſanius Agrippa, who was Prime Miniſter and Son-in-law to Auguſtus, and which is ſo often quoted by Pliny, as a Menſuration of great Authority; and as this was a Buſineſs too large to be executed by him in Perſon, it is not unlikely that it was performed by three ſuch Surveyors under his Countenance and Protection; and indeed the Period of Time ſeems to point out and confirm this Hypotheſis: For this Survey was begun in the Year 44 before Chriſt, in which Julius Cæſar was killed in the Senate Houſe; and as his Power was ſoon after devolved upon Auguſtus, therefore the Execution of this Survey, as one of the Plans of his Uncle Julius Cæſar, was in a manner bequeathed to the Nephew, and muſt have be-

come a proper Object of the Attention of his Miniſters. It was finiſhed likewiſe in the Year 19 before Chriſt, when Agrippa was in the Plenitude of his miniſterial Power, and juſt five Years before his Death.

The Roman Itineraries that are ſtill extant, ſhow evidently with what Accuracy their Surveys were made in every Province; and *Pliny* has filled the Third, Fourth, and Fifth Books of his Natural Hiſtory with the Geographical Diſtances that were thus meaſured. We have likewiſe one ancient Set of Maps ſtill preſerved to us, known by the Name of *the Peutingerian Tables*, publiſhed by Welſer and Bertius, which give us a ſufficient Specimen of what Vegetius calls

calls the *Itinera Picta*, for the clearer Direction of the March of their Armies.

The Roman Empire had been enlarged to its greateſt Extent, and all its Provinces well known and ſurveyed, when Ptolemy, in the Days of Antoninus Pius, about 150 Years after Chriſt, compoſed his Syſtem of Geography, which has been happily preſerved to us amidſt the general Wreck that conſumed ſo many other Books of Science. The Materials then extant, and in his Poſſeſſion, for the completing of that great Work, conſiſted of various Particulars, ſome of greater and others of a leſs Degree of Authenticity. The Principal were the *Proportions of the*

Gnomon to its Shadow, taken by different Aſtronomers at the Times of the Equinoxes and Solſtices; *Calculations* founded upon the Length of the longeſt Days; *the Meaſures* or computed Diſtances of the principal Roads contained in their Surveys and Itineraries, and the various *Reports of Travellers and Navigators*, who often determined the Intervals of Places by Hearſay and Gueſs-work. All of theſe were to be compared together, and digeſted into one uniform Body or Syſtem, and after this were converted and tranſlated by him into a new mathematical Language, expreſſing their different Degrees and Minutes of Latitude and Longitude, according to the Invention of Hipparchus, but which Ptolemy had the Merit

Merit of carrying into full Practice and Execution, after it had been neglected for upwards of 250 Years.

For I believe no Author has ever ſuppoſed that Ptolemy had in his Poſſeſſion real aſtronomical Obſervations ſufficient to determine all the Longitudes and Latitudes he has given; ſo that we muſt always remember, that their degree of Accuracy depended upon the Veracity of the Fact or Suggeſtion communicated to him, from which they were afterwards deduced. Agreeable to this Idea, we find that Regiomontanus, in his Commentary upon Ptolemy's Geography, quoted by Geſner, though never publiſhed, endeavoured to explain an Inſtrument called *Meteoroſcopium*, by which

he ſuppoſes Ptolemy reduced and brought forth the Numbers of his Geography *.

We muſt not therefore be aſtoniſhed at the Multitude of Errors to be found there, when his original Materials were ſo imperfect for executing ſo large a Work as the fixing the Longitudes and Latitudes of all the Places, Coaſts, Bays and Rivers of the then known World; an Undertaking which, even in our Days, has not hitherto been

* Commentaria in Coſmographiam Ptolemæi, ubi exponitur fabrica uſuſque Inſtrumenti Meteoroſcopii, quo Ptolemæus ipſe univerſos fermè numeros totius operis ſui elicuit: falſo enim quiſpiam crediderit, tot longitudinum latitudinumque numeros per ſupernorum obſervationes innotuiſſe. Geſneri Bibliotheca, p. 439.

brought

brought to any ſufficient Degree of Accuracy.

It was almoſt impoſſible for him not to have committed many Miſtakes in the Places beyond the Extremities of the Roman Empire, which were indeed out of the Range both of Aſtronomers and Surveyors. So that thoſe learned Writers who have ſo ſharply criticiſed ſome few of his Errors in theſe Particulars, have not treated him with that Candour which a Work of this Nature deſerved. For his Miſtakes aroſe from the Ignorance of the Age in which he lived, which could give him no better Information, and were not properly the perſonal Ignorance of the Author. And this is a Remark which ought to have its

due Weight in reſtraining the Wantonneſs of Criticiſm in a thouſand Inſtances. *Ricciolus*, *Cellarius*, *Paul Merula*, and *Salmaſius*, have all of them * committed this Miſtake in their Cenſures of his Geography, as if they were diſappointed in not ſeeing this Science in its full Maturity in the Writings of Ptolemy; at a Time when it was evidently but juſt beginning to advance beyond the Verge of its earlieſt Infancy. They might with equal Juſtice condemn the modern

* Riccioli Geogr. Præf. Cellarii Notitia Orbis Antiqui Præf. Paul Merula in Præf. Geogr. Salmaſius in Solinum, p. 1186. etiam Gherardus Mercator in Præf. Ptolemæi Geogr. Philip Cluverius in Geographia. Velſerus in Rerum Auguſtanarum Libris. See Fabricii Biblioth. Græc. vol. 3. p. 414.

Geographers

Geographers for giving no better Account of Nova Zembla, or New Holland, or of thoſe Continents and Iſlands that lie on the Northern or Southern Extremities of the Great South Sea towards the two Poles.

If the Obſervations from which Ptolemy compiled his Geography had been as faithful and accurate as the Principles upon which it was digeſted were certain, then this Science would have advanced much ſooner towards its full Maturity. But when Premiſes are admitted to be true, which are either doubtful or falſe, then the Concluſions drawn from them muſt always be erroneous. Now the principal Miſtakes in Ptolemy took their Riſe from certain aſtronomical Obſervations

and

and Surveys which were ſuppoſed to have been made with Accuracy in an Age prior even to Ptolemy himſelf; and as that great Author received and adopted them as genuine, having none more authentick by which their Accuracy might have been tried, and having otherwiſe no reaſon to ſuſpect them; ſo ſucceeding Geographers, for want of better Information, were induced to copy and inſert them in their Maps, as being, in their Opinion, of acknowledged and undoubted Authority. And thus Error, when it has once aſſumed the counterfeit Stamp of Truth by the haſty and unguarded Conceſſion of ſome eminent Writer, often preſerves its Currency during an amazing Length of Time. For theſe capital Miſtakes

kept

kept their Place in all Maps whatever, by a Sort of unqueſtioned Preſcription, down even to the Beginning of the preſent Century.

Neither were theſe Errors ſuch as were introduced in the more diſtant Extremities of his Maps, which are generally leſs viſited and more uncertain; but they were in the very Center of that Part of the World which was the beſt known to the ancient Greeks and Romans. For whoever is the leaſt converſant in their Hiſtory, muſt know that the Coaſts of the Mediterranean were the claſſic Ground of all Antiquity; War and Commerce occaſioned its being inceſſantly traverſed by the Ships of all the contiguous Nations; ſeveral great Em-

pires

pires had their Capitals upon its Shores, or at a few Miles Diſtance; and almoſt all the ancient practical Aſtronomers made their Obſervations in its Neighbourhood.

I ſhall mention at preſent only *three* Inſtances of thoſe Errors, the Conſequences of which I ſhall explain afterwards at greater length.

The *firſt* is that of *Byzantium*, which, according to Ptolemy, is in the Latitude of — — —	43° 5′ *
But by the beſt modern Obſervations is only —	41° 1′
Error in Ptolemy is --	2° 4′

equal

* In all the Editions of Ptolemy they by Miſtake make it 43° 6′ in the Latin Column, when

equal to 124 geographical Miles, or allowing 69 Engliſh meaſured Miles to a Degree, it will amount to 142 meaſured Miles. This Miſtake in Ptolemy was occaſioned by the following Paſſage in Strabo, lib. 2. p. 134.

Ἐν δὲ τοῖς περὶ τὸ Βυζάντιον, ἡ μεγίστη ἡμέρα ὡρῶν ἐστιν ἰσημερινῶν δεκαπέντε καὶ τεταρτημορίου, ὁ δὲ γνώμων πρὸς τὴν σκιὰν λόγον ἔχει ἐν τῇ θερινῇ τροπῇ ὃν τὰ ἑκατὸν εἴκοσι πρὸς τεσσαράκοντα δύο, λείποντα πέμπτῳ.

" That at Byzantium the longeſt
" Day was fifteen equinoctial Hours
" and a Quarter, and that the Pro-
" portion of the Gnomon to its Sha-
" dow at the Summer Solſtice was
" as 120 to 42 wanting one Fifth, or
" in other Figures as 120 to $41\frac{4}{5}$."

when the Greek Figures are μγ. ιβ. which are $43\frac{1}{12} = 43° 5'$.

Strabo

Strabo * has mentioned in four other Paſſages of his Geography, that the ſame Proportion as at Byzantium was found at Marſeilles by Pytheas, and was taken notice of as ſuch both by Eratoſthenes and Hipparchus.

As the Trigonometry made uſe of by Ptolemy was leſs accurate than at preſent, he had therefore determined, from the above Particulars in a groſſer Manner, the Latitudes of Byzantium and Marſeilles to be 43° 5′; whereas by a more accurate Trigonometry, according to the Length of the longeſt Day of fifteen Hours and a Quarter, without correcting it from Refraction

* Strabo, lib. 1. p. 63. lib. 2. p. 71. p. 106. & p. 115.

and

and Parallax, and ſuppoſing, with Ptolemy, that the Sun's Declination at that time was 23° 51′ 20″, his Concluſion ought to have been that the Latitude was 43° 1′ 24″; and if that was calculated by the ſecond Method of the Proportion of the Gnomon to the Shadow of 120 to $41\frac{4}{5}$, and admitting the ſame Declination, it would be 43° 3′ 38″. From both of which it clearly appears, that Ptolemy was in this Particular miſled by Hipparchus, who is mentioned by Strabo as having viſited Byzantium, and made this very Obſervation in Perſon*. It is the more ſurpriſing how this accurate Aſtronomer ſhould have made ſo groſs

* Ὁι γαρ λόγοι εἴρηκε τῶ ἐν Μασσαλίᾳ γνώμονι πρὸς τὴν σκιάν, τὸν αὐτὸν καὶ Ἱππαρχῳ· καὶα τον ὠμώνυμον καιρὸν ἑυρειν ἐν τῳ Βυζαντίῳ φησιν. Strabo, lib. 1. p. 63.

a Miſtake,

a Miſtake, when we recollect the Character given him by Ptolemy, Ἱππάρχῳ ἀνδρὶ φιλοπόνῳ τε ὁμοῦ, καὶ φιλαλήθει, *a Lover of Labour and a Lover of Truth* *; and in another Paſſage he diſtinguiſhes him by the Epithet of φιλαληθεςάτου, *a Lover of Truth in the ſuperlative Degree* †; which he was well juſtified in giving him, from a Number of Inſtances of his great Veracity and Candour which he has adduced in the Courſe of that Work.

The Latitude of Marſeilles, which was ſuppoſed to be under the ſame Parallel with Byzantium, was not however ſo much miſtaken, as by the beſt modern Obſervations it is found to be 43° 17′ 45″. And as in the

* Ptolemy, Almag. p. 59.

† Almag. p. 210.

above

above Calculation there is a Doubt * whether the Sun's Semidiameter was ſubtracted from the Altitude, as the Line which bounded the Shadow muſt have come from the upper Limb of the Sun, therefore we muſt add 15′ 47″, the Sun's Semidiameter at the Summer Solſtice, to 43° 3′ 38″, which will make the Latitude of Marſeilles to be 43° 19′ 25″, which is only a Difference of 1′ 40″, from the lateſt that has been found by the beſt Inſtruments of Obſervation.

If we ſhould invert this Calculation, we ſhall find what was the Sun's greateſt Declination in the Days of Pytheas, about 300 Years before the Chriſtian Æra, by admitting the Latitude of Marſeilles to be 43° 17′ 45″,

* Gaſſendi Opera, Tom. 4. p. 527.

45″, and the Sun's greateſt Altitude according to the Proportion of 120 to $14\frac{4}{5}$, to be — — 70° 47′ 42″ 15‴

Subtracting the Sun's Semidiameter at the Summer Solſtice — 15′ 47″

The Sun's Altitude corrected — 70° 31′ 55″ 15‴

The Sun's Zenith Diſtance — 19° 28′ 4″ 45‴

Which being deducted from the Latitude 43° 17′ 45″

Gives the Sun's greateſt Declination in the Days of Pytheas — 23° 49′ 40″ 15‴

The mean Obliquity of the Ecliptic, or greateſt Declination at preſent in the Beginning of the Year 1768 — 23° 28′ 10″

The Diminution of the Declination in 2068 Years is therefore — 21′ 30″ 15‴

which is nearly at the Rate of 62″ 23‴ every hundred Years.

But

But if we ſhould determine the Rate of this Diminution from a more accurate Obſervation made by *Albategni* about the Year 880, when he found the Obliquity of the Ecliptic to be 23° 35′, to which if 40″ is added for the Refraction after deducting the Parallax *, neither of which were at that Time attended to or known, then the Obliquity of the Ecliptic in his Time will ſtand — — — 23° 35′ 40″

The mean Obliquity at preſent — — — 23° 28′ 10″

The Diminution in 888 Years, being from 880 to 1768 — — 7′ 30″

which is nearly at the Rate of 50″ in every 100 Years, or half a Second each Year.

The mentioning this Obſervation of Pytheas at Marſeilles, makes it neceſſary to explain here a little more

* M. de la Lande's Aſtronomie, § 2179. p. 1027.

fully

fully this Queſtion *of the Variation of the Sun's Declination*, which was a Subject much controverted by ſome of the greateſt Aſtronomers of the laſt two Centuries, as well as at the Beginning of the preſent. And it is an additional Reaſon for entering more particularly into this Detail, becauſe all Obſervations of Latitude in different Ages taken from the Sun's Altitude, require to be illuſtrated by a previous Knowledge of the State of this Queſtion.

I ſhall therefore firſt give a View of the Obſervations made by Aſtronomers in different Ages of the Sun's greateſt Declination, as they are collected by *Ricciolus* in his *Almageſt*, Vol. 1. p. 162, and I ſhall add the

Continuation

Continuation of it from M. *De la Lande's Aſtronomie*, p. 1028, down to the preſent Year.

ASTRONOMERS.

	Y. bef. C.	D.	M.	S.
Pytheas of Marſeilles, as above — — —	300	23	49	40 15‴
Ariſtarchus of Samos, in the 50th Year of the 1ſt Calippic Period	280	24	0	0
The Indians quoted by Meſſahala, cap. 1. part 2. Aſtrolabii —		24	0	0
Eratoſthenes of Cyrene	230	23	51	20
Hipparchus of Rhodes	140	23	51	20
	Aft. Chr.			
Ptolemy of Peluſium, Almageſt. lib. 1. p. 17 & 18. —	140	23	51	20
Almamon, Caliph of the Saracens, according to Alfraganus —	830	23	35	0
Albategni of Aracta De Scient. Stell. cap. 4. p. 14. Ed. 1645. —	880	23	35	0

ASTRONOMERS.

	Y. of C.	D.	M.	S.
Arzachel of Toledo —	1070	23	34	0
Almæon the Son of Almanſor the Arabian	1140	23	33	30
Thebit Ben Corah —	1210	23	33	30
according to others	1287			
Prophatius the Jew —	1300	23	32	0
Purbachius and Regiomontanus —	1460	23	28	0
but by their Obſervations being corrected — —		23	30	0
Petrus Nonius —	1500	23	30	0
Dominicus Maria —	1500	23	29	0
Jo. Vernerus —	1510	23	28	30
Nicolaus Copernicus	1525	23	28	24
but being corrected by Ricciolus —		23	30	47
Petrus Apianus —	1530	23	30	0
Orontius Finæus —	1555	23	30	0
Egnatius Dantes —	1570	23	29	0
but being corrected		23	30	30
Aſtronomers under the Landgrave of Heſſe Caſſel — —	1570	23	31	0

Jo. Homelius

ASTRONOMERS.

	Y. of C.	D.	M.	S.
Jo. Homelius at Leipſick	1570	23	29	30
Tycho Brahe —	1586	23	31	30
but from ſome other of his ſelect Obſervations with the Corrections of Ricciolus	1586	23	30	36
	1587	23	29	30
	1589	23	30	45
	1593	23	30	0
N. B. Tycho was the firſt Aſtronomer who made Allowances for the Errors in Obſervation from Refraction.				
Philip Lanſberg —	1589	23	30	10
but corrected by Ricciolus — — —		23	29	30
Clavius, Scheinerus & Galileo — — —	1600	23	30	0
Vendelinus according to his own Parallax ——	1620	23	30	15
but according to that of Ricciolus ——		23	30	30
Peter Gaſſendi ——	1630	23	31	0
Ricciolus ——	1643	23	30	0
Bullialdus ——	1645	23	32	0

ASTRONOMERS.

	Y. of C.	D.	M.	S.
Caſſini by the Gnomon in the Church of St. Petronius at Bologna —	1655	23	29	0
M. Richer at Cayenne, according to Caſſini —	1672	23	28	54
Mr. Flamſtead —	1689	23	28	56
M. Bianchini —	1703	23	28	35
M. Horrebow —	1709	23	28	47
M. De Louville. Memoires de l'Academie 1714, p. 88.	1714	23	28	41
The ſame from Obſervations at Marſeilles. Memoires de l'Academie, 1716, p. 59. — —	1716	23	28	24
M. De la Condamine at Quito — —	1736	23	28	24
Dr. Bradley and M. De la Caille — —	1750	23	28	19
Mr. Maſkelyne, January 1ſt	1768	23	28	10

From the Uniformity of the above Table it is evident, after making all reaſonable

reaſonable Allowances for the Coarſeneſs of the Inſtruments of the earlier Aſtronomers, that we cannot deny the Diminution of the Obliquity of the Ecliptic, without doing Violence to the Obſervations of all the paſt Ages.

And yet this Poſition in Aſtronomy hath had a various Fluctuation of Opinion concerning it, having been adopted by ſome great Aſtronomers, and afterwards rejected and exploded by others of equal Abilities and Reputation, till at laſt, Time, which is the great Touchſtone of Truth, by the Aſſiſtance of better Inſtruments of Obſervation, has at laſt eſtabliſhed it beyond the Power of Contradiction.

Thebit Ben Corah, the Arabian Aſtronomer, who, according to ſome, flouriſhed in the IXth, and according to others, in the End of the XIIIth Century, was the firſt who aſſerted *the Variation of the Sun's Declination* under the Name of *the Motion of Trepidation.*

This Opinion was reſumed upon the Revival of Aſtronomy in Europe by *Purbachius* and *Regiomontanus, Copernicus, Tycho, Lanſberg, Longomontanus, Kepler, Vendelinus,* and many others. Some of thoſe Writers conſidered this apparent Change of Declination to be owing to a ſmall *periodical Vibration of the Axis of the Earth*; and being over deſirous of completing an Hypotheſis before there

there were ſufficient Data, they went even ſo far as to determine the *Maximum* and the *Minimum* of this Vibration, pretending to fix the very Year when it changed its Direction and began to increaſe. And as it is too common for many ingenious Men to make all their Knowledge to aſſume the Form of a Syſtem, which is the great Bane of Science, they endeavoured to calculate and apply theſe critical Periods to the Creation and Birth of our Saviour, with which it is now clear and evident that they have no Connexion.

The oppoſite Opinion that the Obliquity of the Ecliptick had been invariably the ſame in all Ages, was maintained by *Gaſſendi*, *Kircher*, and

Ricciolus, who endeavoured to explain away the Appearances of Variation from the imperfect Manner in which the Ancients obſerved, and from the Contradiction and Inconſiſtency in many modern Obſervations, of which indeed the Examples were too frequent. And they were the more inclined to this Idea of no Variation whatever, foreſeeing that a gradual Diminution of Declination would introduce a new Principle of Corruption into the very Stamina of all aſtronomical Tables. For there muſt be new Calculations made from time to time of oblique Aſcenſions, the Latitudes of the Planets and fixed Stars, the Semidiurnal Arcs, and the very Motion of the Sun himſelf deduced from Declination, beſides the

infinite

infinite Number of Problems which depend upon Latitude. They therefore concluded it much more probable to ſuppoſe "God Almighty to "have WILLED that there ſhould be "for ever *one and the ſame Royal High-"way*, namely, the Ecliptick, through "which the Sun ſhould appear to "make his invariable Path, and which "ſhould be the conſtant Line and "Boundary for determining the Lati-"tudes of all the Planets *."

Theſe and other Reaſons made ſo general an Impreſſion on the Aſtronomers of the laſt Century, that this Idea, *of there being no Change whatever in the Obliquity of the Ecliptick*,

* Riccioli Almageſt. Vol. 1. p. 164.

became the prevailing Opinion in Aſtronomy for upwards of fifty Years; with this difference however, that 23° 30′ was ſuppoſed to be *the invariable Declination*, according to Ricciolus and others; whereas Meſſieurs *Flamſtead* *, *De la Hire* and *Caſſini*, who were the great practical Aſtronomers at the Beginning of the preſent Century, lowered their Station one Minute, and adopted that of 23° 29′.

M. *De Louville* once more revived the Theory of *the Variation of the Obliquity*, in two ingenious Papers publiſhed in the Memoires de l'Academie

* Flamſteedii Hiſtoria Cœleſtis, Vol. 3. Prolegom. p. 124.

des

des Sciences for 1714 and 1716, where M. de Fontenelle, in giving his Account of the laſt of theſe, has the following Obſervation: "*Malgré toutes les raiſons de* M. *de Louville, les autres Aſtronomes de l'Academie ſont demeurés attachés à l'Obliquité conſtante de l'Ecliptique de* 23° 29′ *" And agreeable to this there is a Paper publiſhed by M. De la Hire in the Memoirs of the ſame Year, 1716, in defence of his own Opinion and that of the reſt of the Academy.

But the more ancient Doctrine of *the Diminution of the Obliquity of the Ecliptick*, was at laſt completely reeſtabliſhed by the accurate Obſer-

* Memoires de l'Academie R. des Sciences pour 1716, p. 64. 8vo.

vations of Dr. *Bradley*, publiſhed in the Philoſophical Tranſactions of 1737, where he not only clearly proves the uniform leſſening of the Declination, but has diſcovered a ſmall periodical Variation of 18″ in this Diminution, increaſing and leſſening its Quantity by turns, according to the Revolution of the Nodes of the Moon which is called *the Nutation of the Earth's Axis.*

Bullialdus, in his *Aſtronomia Philolaica*, publiſhed in the Middle of the laſt Century, when he acknowledges the Variation of the Declination, has added his Opinion, " that it was im-
" poſſible to inveſtigate thoroughly
" the phyſical Cauſe of this Motion;
" we know, ſays he, the Reality of

the

" the Fact, but are ignorant of the " Principle; neither can the utmoſt " Force of human Genius diſcover " theſe Cauſes *."

But M. *Euler*, not intimidated with this *Dictum*, and juſtly conſidering, *that every Effect uniformly produced muſt have a phyſical Cauſe*, has applied with great Propriety the Neutonian Syſtem of Gravitation to the Solution of this Difficulty, by ſhewing that the Attraction of the different Planets upon the

* Cauſam porro illius motûs phyſicam inveſtigare penitus impoſſibile eſt, ſcimus rem eſſe, ſed cauſam illius ignoramus, nec poteſt humani ingenii acumen pervidere cauſas illas. Bullialdi Aſtronomia Philolaica, lib. 5. cap. 5. p. 229.

Earth

Earth ought to produce this Effect *, and that too in the very Proportion in which it appears in Nature.

This Digreſſion concerning the Obliquity of the Ecliptick, took its Riſe from the Obſervation of the Proportion of the Gnomon to its Shadow, recorded in Strabo, from which Ptolemy was led into an Error with regard to the Latitude of Byzantium, to which I ſhall now return.

* M. Euler's Paper is in Tom X. of the Mémoires de Berlin ſur les Inegalités de Saturne, p. 79. See likewiſe two Papers of M. De la Lande dans les Mémoires de l'Académie de Sciences pour 1758 & 1761. And his Aſtronomie, § 2186, &c. p. 1029, &c.

The *Arabians*, who copied after Ptolemy's Geography, inſtead of correcting this Error of the Latitude of Byzantium, increaſed it to double the Quantity, as if they had been acquainted in general that there was a Miſtake of two Degrees without being told on which Side, and therefore they unfortunately added the two Degrees to the 43° given by Ptolemy, inſtead of ſubtracting them; for all their Geographers * make the Latitude of Byzantium or Conſtantinople 45° inſtead of 41°, which was an Er-

* Abulfeda, Naſſar Eddin, Ulug Beg, Binæ Tabulæ Geogr. editæ a Jo. Gravio 1652. See likewiſe J. Greaves's Letter to Archbiſhop Uſher, publiſhed in the Philoſophical Tranſactions, N° 178, for December 1685.

ror

ror of four Degrees, amounting to no leſs than 240 Geographical Miles, or to 276 Britiſh meaſured Miles.

It is ſurpriſing that the true Latitude of Conſtantinople was ſo groſsly miſtaken, and continued unknown for ſo long a Time, though it was the Metropolis of the eaſtern Empire, and afterwards of that of the Turks. For Amurath III. who was a Cotemporary of Queen Elizabeth, having begun his Reign in 1574, and died in 1595, appears from two Letters of Vendelinus to Gaſſendi *, to have been the firſt who took the proper

* Gaſſendi Opera, Tom. VI. p. 427. & p. 511.

Steps

Steps to have it known. The Aſtronomers employed by him having found that in that Part of the City called Topchana, its Latitude was 41° 30′, and its Longitude 56° 47′. Haga, the Dutch Envoy, who gave Vendelinus this Account dated from Conſtantinople 30th April 1633, adds, that all the Arabian Mathematicians there, were of the ſame Opinion; though he mentions at the ſame time, that there were no Aſtrolabs in that City fit for making an Obſervation. Vendelinus, who ſtill had greater Faith in the Obſervation as given by Hipparchus, adds the following Words: *Vix bilem tenebis ſcio, vix riſum, Mi Gaſſende, ubi hæc leges, ego ſcio Byzantii Latitudinem*

Latitudinem Peræ inveniendam 43 *grad.* 20 *min. Serralii proin ac veteris Byzantii* 43 *grad.* 19 *min. ſi verum eſt Hipparchum inveniſſe illic eandem umbram ſolſtitialem quam Pytheas Maſſiliæ.*

This Obſervation under *Amurath* III. had ſtill an Error of making the Latitude of Conſtantinople betwixt twenty and thirty Minutes too much, as was found by *John Greaves* in 1638, who, being ſent into the Eaſt by Archbiſhop *Laud* for the Purpoſe of purchaſing oriental Manuſcripts, found the Latitude there to be 41° 6′ by means of a Braſs Quadrant of four Foot Radius *; it has been ſince more

* Philoſophical Tranſactions for December 1685, and Greaves' Works, Vol. II. p. 364.

accurately

accurately obſerved by M. *Chazelles* * in 1694, and found to be 41° 1′ 0″

By M. Condamine in 1731. — 41° 0′ 0″

Upon the oppoſite Shores of the Mediterranean, though much more weſterly, ſtood *ancient Carthage*.

Ptolemy has placed it in the Latitude of — 32° 20′ 0″

But its Latitude, according to the beſt Obſervations, is — 36° 52′ 0″

Error in Ptolemy — 4° 32′ 0″

equal to 272 geographical Miles, or 313 Britiſh meaſured Miles.

* Mémoires de l'Académie des Sciences pour 1721, p. 75. and pour 1732, p. 404. 12mo.

This

This, which is the *ſecond Error*, appears to have been founded upon the following Paſſage in Strabo, lib. 2. p. 133. Ἐν Καρχηδόνι ὁ γνώμων λόγον ἔχει πρὸς τὴν ἰσημερινὴν σκιὰν ὃν ἔχει τὰ ἕνδεκα πρὸς τὰ ἑπτα. *In Carthage the Gnomon has the ſame Proportion to the Equinoctial Shadow which* 11 *has to* 7. Now by plain Trigonometry this Proportion muſt give us the Latitude of 32° 28′, which being ſo near the Latitude adopted by Ptolemy, is a ſtrong Preſumption that his Latitude was copied or tranſlated from the Obſervation as related by Strabo.

Such was the Ignorance of the World in Matters of Geography, that this remarkable Miſtake which affected the whole Coaſt of Africa, from the

Straits

Straits of Gibraltar to the *Cape of Mercury*, now called *Cape Bona*, ſtood unnoticed till the Beginning of the laſt Century, when Snellius, in a Letter to Gaſſendi dated July 20th 1625, ſays, that by Gaſſendi's Obſervations he had diſcovered an Error in Ptolemy's Latitude of Carthage of three Degrees. *Atque adeo Ptolemæum quoque in Latitudine Carthaginis Hipponis Regiæ facile tribus gradibus aberrare. Id clariſſimè veſtræ Obſervationes coarguunt, pro quibus Geographiæ totius nomine, vobis & veſtræ diligentiæ gratulor, earum enim expers ſecundùm Ptolemæum pronunciâſſem* *.

See likewiſe a Paper of M. Deliſle in in the Mémoires de l'Académie des Sciences pour 1714, p. 236. 12mo.

* Gaſſendi Opera, Tom. VI. p. 393.

The

The Length of the Mediterranean is the *Third* capital Miſtake in Ptolemy's Geography. It is generally meaſured from the Straits of *Gibraltar* to the Bottom of the *Bay of Iſſus*, where Alexandretta, or Scanderoon, now ſtands, whoſe ancient Name was *Alexandria ad Iſſum*, to diſtinguiſh it from other Cities of the ſame Deſignation.

The Longitude of *Alexandria ad Iſſum* from the Canaries, or Fortunate Iſlands, according to Ptolemy *	69°	30′
The Longitude of *Gibraltar*, anciently *Calpe*, or *the Pillar* (viz. of Hercules) *in the Inner Sea*, στήλη τῆς ἐντὸς θαλάσσης, according to the ſame † — — —	7°	30′
Their difference of Longitude according to him ‡ — —	62°	0′
The difference of Longitude between theſe two Places according to the lateſt Obſervations —	41°	28′
The Error in Ptolemy —	20°	32′

* Ptolem. Geogr. p. 137. † Ibid. p. 35.

‡ *Snellius*, by miſtake in his *Eratoſthenes Batavus*, lib. 2. p. 232, ſays, that Ptolemy made it to be nearly 68° 30′, and propoſes a Correction of his own, as if it ſhould be 62° 31′.

This

This amazing Miſtake which Ptolemy committed in over-rating the Length of the Mediterranean, and which continued in all our Maps more or leſs till the Beginning of the preſent Century, took its Riſe from the ſuppoſed Surveys of different Perſons of Reputation recorded by Strabo, ſeveral of whom ſeemed to confirm the Authority of each others Computation, by entering into the ſmalleſt Intervals of Diſtances with an Appearance of Accuracy, and then bringing it nearly to the ſame Meaſurement; ſo impoſing is that Concurrence of the various Teſtimonies of Error, that gives it now and then for a Time the Colour and the Semblance of Truth.

Strabo

Strabo * ſays, the greateſt Number agreed in allowing that the Diſtance from the Bay of Iſſus to the weſtern Extremities of Spain, was a little leſs than 30,000 Stadia; and as he mentions that from the Columns to the weſtern Part of Spain, called the Sacred Promontory, now Cape St. Vincent, was a Diſtance of 3000 Stadia, therefore the Diſtance from Gibraltar to Iſſus was leſs than 27000 Stadia; in the Detail which he gives afterwards he makes it 26500 and upwards, in the following manner.

	Stadia.
From *the Bay of Iſſus* to *Rhodes*	5000
From *Rhodes* to *Salmonium*, being the eaſtern Promontory of Crete	1000

* Ομολογουσι γαρ οι πλειστοι, &c. Strabo, lib. 2. p. 106.

From

	Stadia.
From *Salmonium* to the *Ram's Head*, ἐπὶ Κριὸς μετοπον, being the weſtern Promontory of Crete — —	2000
in this Diſtance he ſays more than two thouſand, πλείας ἢ δισχίλιας.	
From thence to *Pachynus*, being the South-eaſtern Promontory of Sicily	4500
From *Pachynus* to the *narrow Sea*, ἐπὶ πορθμον, viz. betwixt Sicily and Africa, more than a thouſand πλείας ἢ χίλιας — — — — —	1000
From the *narrow Sea* to the *Columns* (viz. of Hercules) or Gibraltar —	13000
	26500

If we reduce theſe to Degrees of Longitude by Ptolemy's * Method of allowing 400 Stadia to a Degree of Longitude upon the Parallel of 36°,

* Ptolem. Geogr. lib. 1. cap. 11. p. 11.

it will make the Length of the Mediterranean to be 66° 15′ and upwards, which is only 4° 15′ more than what are given by Marinus whom * Ptolemy ſtrictly adhered to in this Computation.

From *Calpe* to *Caralli* in Sardinia, now *Cagliari* —	25°	0′
From *Caralli* to *Lilybæum* in Sicily — — —	4°	30′
From *Lilybæum* to *Pachynus* —	3°	0′
From *Pachynus* to *Tænarus* in Laconia — — —	10°	0′
From *Tænarus* to *Rhodes* —	8°	15′
From *Rhodes* to *Iſſus* —	11°	15′
	62°	0′

Pliny has likewiſe given us two Computations of this Diſtance, one

* Ptolem. Geogr. lib. 1. cap. 12. p. 13.

from

from Polybius, and the other from Agrippa, which I ſhall firſt ſtate in his own Words *.

Polybius — ab eodem initio (viz. Gaditano freto) ad Orientem recto curſu Siciliam XII LX mill. ccccc paſſuum. Cretam CCCLXXV. M. paſſ. Rhodum CLXXXVI. M. CCCCC. paſſ. Chelidonias tantundem. Cyprum CCCXXV. M. paſſ. Inde Syriæ Seleuciam Pieriam † CXV. M. paſſuum. Quæ computatio efficit vicies *ter* (lege *quater* ſecundùm Hardouinum) centena XL. M. paſſuum. Agrippa hoc idem in-

* Pliny, lib. 6. cap. 33.

† *Pieria Seleucia* was a little to the South of *the Bay of Iſſus*, and being under the ſame Meridian, they were equally diſtant from the Straits of Gibraltar.

tervallum a freto Gaditano ad Sinum Iſſicum per longitudinem directam XXXIIII. XL. paſſuum M. taxat, in quo haud ſcio an ſit error numeri,— hæc eſt menſura inermium, & pacata audacia fortunam provocantium hominum.

The Numbers of Polybius in the Detail, make the Diſtance amount to 2448½ Roman Miles; but when he ſums it up he calls it 2440 Miles, according to Hardouin's reading from the Chiffletian MS.; for 2340 would have contradicted the very Numbers he had given. Agrippa computes the ſame Diſtance to be 3440; but Pliny, when he quotes this, adds a Suſpicion of his own, as if there was an Error in the Numbers of Agrippa, *in quo haud*

haud ſcio an ſit error numeri; inſinuating as if the two Diſtances were perhaps the ſame in the two Authors, as the adding one x too much in the Numbers of Agrippa, might occaſion the Difference of one thouſand Miles in his Computation exceeding that of Polybius, and being really, as I ſhall make it appear, the Exceſs above the true Diſtance.

Let us therefore ſuppoſe that Ptolemy had adopted the Numbers of Polybius, and made the Tranſlation or Reduction of them into Degrees and Minutes, we ſhall find that it would have given him nearly the true Difference of Longitude of the Mediterranean, as it has been ſince deter-

mined by the moſt accurate Obſervations. For by *Norwood*'s Menſuration, in 1635, of the Diſtance between London and York *, it was found that *a Degree on a great Circle of the Earth* contained 367196 Engliſh Feet, being a little more than 69½ Engliſh Miles; and therefore, by the Proportion of the Radius to the Coſine of the Latitude, 297067 Feet will be found equal to a Degree of Longitude upon the Parallel of 36°. But as the Roman and Engliſh Foot is nearly equal, and 5000 Feet made a Roman Mile, therefore 73 Roman Miles and

* Dr. Wilſon's Diſſertation on *the Riſe of Navigation*, prefixed to Mr. Robertſon's Elements of Navigation, in two Vols. 2d Edition, 1764.

four Tenths will anſwer to a Degree on the Equator, and 59 Roman Miles and four Tenths to a Degree of Longitude on the Parallel of thirty ſix Degrees of Latitude.

Now if we divide 2448.5 by 59.4, it will give us 41° 13′; or if we take it only to be 2440, it will give us 41° 4′ for the Length of the Mediterranean from Gibraltar to the Bay of Iſſus, according to Polybius. And as both of theſe differ very little from the Longitude of 41° 28′, which is found by the beſt modern Obſervations, I muſt confeſs that this Degree of Exactneſs and Coincidence of Computation is to me altogether aſtoniſhing, and is a new Confirmation

of the great Accuracy of the Ancients in their Surveys *.

If we next take the Meaſure given by Agrippa of 3440, in which Pliny ſuſpects there was a Miſtake, and divide it in the ſame manner by 59.4, it will give us 58° 20′ for the Length of the Mediterranean, according to Agrippa: But as the Length given by Strabo amounted, as I have already mentioned, to 66° 15′, therefore Ptolemy ſeems to have taken a middle Path betwixt theſe two erroneous Computations of Strabo and Agrippa, when he adopted that of 62°.

* See a Paper of M. Deliſle's upon *the Meaſures of the Ancients* in Matters of Geography. Dans les Mémoires de l'Academie des Sciences pour 1714.

The

The great Misfortune of ancient Geography, and which indeed confined it to ſuch a lingering State of Infancy, was, that the true Method of determining with Accuracy the Difference of Longitudes was a Matter of ſuch Difficulty, and remained ſo long unknown. It is not therefore ſo much to be wondered at, that almoſt all the Longitudes given by Ptolemy are erroneous, and that this remarkable Miſtake, in particular, continued undiſcovered and uncorrected for many Centuries together.

One of the firſt Attempts to rectify the Length of the Mediterranean, was made under the Auſpices of *Monſieur de Peireſk* in 1635. He was one of the moſt eminent Men of his Time;

and if we may judge from his Life, wrote by Gaſſendi, no Perſon contributed more effectually to the Reſtoration of Learning upon clear and ſolid Principles, which began then to be better underſtood, and to make quicker Advances than it had done in any former Age.

Gaſſendi informs us *, that M. de Peireſk, with a direct View to the correcting

* Et omnium quidem obſervata commemorari hæc non poſſunt; ſed taceri tamen non debet, quod pro votis Peireſkii fuit, conſtitiſſe exinde Tabulas Chartaſque Geographicas omnes nimis a nobis abducere illa Ægypti ac Syriæ loca. Quippe cum tribus propè horis, hoc eſt gradibus quadraginta quinque Aleppum Maſſilia Orientaliorem conſtituant; prodiderunt obſervationes integram penè horam detrahendam

correcting the Errors in the Longitudes of different Places, took particular Pains to get Obſervations made at Marſeilles, Aleppo, and Grand Cairo, of an Eclipſe of the Moon which happened in Auguſt (viz. the 27th) 1635. Before that Time the Difference of Longitude between Marſeilles and Aleppo had been ſuppoſed to be 45°, but by theſe Obſervations it was found only to amount to * 30°; ſo that by this a very conſiderable Correction was made in the Length of the Mediterranean, by cutting off

dam eſſe, quod inter hæc loca non plures quàm triginta gradus fuerunt numerati. Gaſſendi Opera, Tom. V. p. 324.

* The real Difference of Longitude has been ſince found to be 31° 58′.

the Difference of one whole Hour, or 15° at once.

Geography was at this Time flattered with the Hopes of being ſoon brought to a fuller State of Perfection than it had ever before attained; for *the Eclipſes of the Sun and Moon* were then thought ſufficient to determine the Longitudes of all Places with a tolerable Accuracy. But when the ableſt Aſtronomers began to apply themſelves to this Branch of practical Knowledge, they ſoon found that from theſe Eclipſes attended to and obſerved, as they were with the utmoſt Care, no clear Deduction could be made of the Longitude of any one Place to any ſufficient Degree of Exactneſs, and the more Obſervers they

they employed at different Places, they generally by that increaſed the Multitude of Contradictions and apparent Differences of Eſtimation.

Ricciolus has collected the Obſervations of no leſs than *fifty-ſix* Eclipſes of the Sun and Moon which had happened from 1560 to 1658, all of which had been obſerved by Men of the firſt Reputation in Aſtronomy in that Age; but when they came to be compared, it was then evident, to the great Mortification of Science, that no two Eclipſes obſerved in the ſame two Places by the ſame Men, ever exhibited the ſame Quantity of Longitude. Nay, it was rare if the very ſame Eclipſe did not give a different Longitude according to the

Obſervation

Obſervation of the ſame Obſervers, taken from the *four critical Times* in every Lunar Eclipſe, which are the BEGINNING, the IMMERSION, the EMERSION, and the END.

It was for theſe Reaſons that ſeveral eminent Aſtronomers, ſuch as Fournier *, Kircher, and even Ricciolus †, gave up the Correction of Geography by the Application of Eclipſes of the Sun and Moon alone, as being a fruitleſs and deſperate Undertaking.

Ricciolus has endeavoured to account for the many Inconſiſtencies that appeared in comparing their Ob-

* Furnerii Hydrograph. lib. 12. cap. 25 & 26.

† Riccioli Geograph. lib. 8. cap. 19. p. 363.

ſervations

ſervations ariſing, as he apprehended, from the following EIGHT different Cauſes.

1ſt. Becauſe there was a kind of Smoke or Umbrago which generally darkened the eaſtern Part of the Moon, before the Diſk really entered either the Umbra or the Penumbra of the Earth.

2d. From the Inequalities upon the Diſk of the Moon, particularly on the eaſtern Side, where the Eclipſes always begin, and is generally termed *Littus Eclipticum*, the Shore of Eclipſes.

3d. From

3d. From the Penumbra of the Earth varying according to the different Denſity of the Air.

4th. From the Atmoſphere of the Earth, being ſeldom exactly ſpherical, ariſing from the Tumor of the Vapours in different Places, by which neither the Cone of the Umbra or Penumbra would be uniform and perfect, which muſt affect the Beginnings and Cloſes of Eclipſes.

5th. From a Sort of Atmoſphere ſometimes obſervable about the Moon, which had been taken notice of by Mæſtlinus in the Eclipſe of April 3d 1605, and by Vendelinus at ſeveral different Times, which occaſioned an

Indiſtinctneſs

Indiſtinctneſs in the Obſervation of the Cloſes of Eclipſes.

6th. From the Moon being like the Stones of Bologna, liable to abſorb and retain the Rays of the Sun after the direct Rays are intercepted, by which there is a ſmall Appearance of faint Light left upon the Diſk, after it is completely immerſed in the Shadow of the Earth.

7th. From the Difference in the Eyes of the Obſervers, which are often quicker or ſlower in their Obſervations of the Beginnings and Ends of Eclipſes, and which cannot even be remedied by the Aſſiſtance of Telescopes.

8th. From

8th. From the Inaccuracy of many in determining the Times of Eclipſes, from the Imperfection of Inſtruments, and the Uſe of them in taking the right Aſcenſions, Azimuths and Altitudes of Stars near the Meridian, or in their Tables of Sines and Logarithms, or in their Calculations from theſe Tables.

Such were the ſuppoſed Cauſes which made the Aſtronomers in the Middle of the laſt Century prefer even common Itineraries and Chorographical Maps to the Eclipſes of the Moon, for determining the Longitudes of Places at a ſmall Diſtance from each other. But when the Intervals were very conſiderable, they did indeed allow that Eclipſes well obſerved might

might be of great Uſe; yet ſtill, however, in thoſe greater Diſtances, they were of Opinion that they ſhould only be admitted under Reſtrictions; for as Errors of 16′ or 20′ of Time, equal to 4° or 5° in Space, were often found to occur, it made them reſolve never to acquieſce in the Longitude as determined by an Eclipſe, unleſs it was otherwiſe contained within the probable Diſtances, examined according to the Chorographical Intervals.

The Length of the Mediterranean was therefore ſtill doubtful and uncertain, and continued a Problem in Geography unreſolved during the greateſt Part of the laſt Century, till at length *the Eclipſes of the Satellites of Jupiter* were made uſe of, and found effectual

effectual for that Purpoſe. They had been firſt diſcovered by *Galileo* * on the 7th of January 1610, by means of the Teleſcopes invented by Metius in Holland in 1608, and the great Advantage that might be derived from them in determining the Longitudes of Places, was conceived very early by that great Aſtronomer, as appears from his *Nuncius Sidereus*, publiſhed in March 1610, which was within two Months of the firſt diſcovery †. After twenty Years ſpent in obſerving them, he ſent a Propoſal

* *Tres* primum primuſque Galilæus, Anno 1610, die 7 Januarii horâ noctis primâ deinde nunquam plures quam *quatuor* prope Jovem *Stellas* detexit. Riccioli Almageſt. Vol. I. p. 489.

† Gaſſendi Opera, Vol. V. p. 275.

to

to *Philip* IV. *King of Spain*, in 1631 *, to introduce the Practice of applying them for the Purpoſes of Navigation and Geography. He afterwards made the ſame Propoſition to the *Dutch* †, who embraced it more readily, being at that Time the great Encouragers of Navigation. In conſequence of which they ſent *Hortenſius* and *Bleaw* ‡, two of their beſt Aſtronomers, to Florence, to attend Galileo in his Obſervations, and to be initiated in all the

* Langrenus initio Selenographiæ.

† Riccioli Geogr. p. 317.

‡ Weidleri Hiſtoria Aſtronomiæ, p. 425. Les Hypotheſes & les Tables de Satellites de Jupiter, par Caſſini, p. 3. Ed. 1693, dans le Récueil d'Obſervations pour perfectionner l'Aſtronomie & la Géographie.

Calculations

Calculations neceſſary for compoſing the Tables of the Motions, Revolutions and Eclipſes of theſe *Medicean Stars*, which was their Appellation at that Time in Italy. But theſe Ephemerides were ſoon interrupted by the Misfortunes which befel Galileo from the Inquiſition in 1633, for his having publickly adopted the Copernican Syſtem, which they were pleaſed to condemn as a moſt dangerous Hereſy: And after obliging him to make a ſolemn Recantation, they firſt impriſoned him, and afterwards ſoftened it by a Confinement for Life in the Village of Arcetri, where he ſoon loſt his Sight; his many Years Obſervation of the Satellites having in all Probability brought that Calamity upon him.

The

The Imperfection of the Teleſcopes of that Age, long retarded the Progreſs of this Diſcovery. * Greaves mentions in a Letter dated from Sienna, Auguſt 25th 1639, that Galileo never made but two good Glaſſes, and theſe were of old Venice Glaſs. What ſome others made uſe of in their Obſervations, were either ſo indiſtinct from the Smallneſs of their magnifying Power, or from the Inexperience of the Obſervers, that they often confounded the Satellites with the fixed Stars that were near them. Thus *Antonius Maria Schyrlæus de Rheita*, a Capuchin, thought he had diſcovered at Cologne, on December 29th 1642, *five new Satellites* round Jupiter, making

* Greaves's Works, Vol. II. p. 480.

up

up the number *nine*, which * Gaſſendi refuted in a Diſſertation wrote on purpoſe, ſhewing that the Capuchin had converted ſome of the fixed Stars in the Conſtellation of Aquarius into Satellites. But notwithſtanding this, *Fontana* and *Zupus*, two Aſtronomers of Naples, perſiſted in the ſame Error; *Fontana* pretending to have obſerved them from 1630 to 1646, when he publiſhed his Obſervations †, mentioning the Days when he has ſeen ſometimes 7, 8 and 9 Satellites, and none of them ever above ten Diameters of Jupiter's Body diſtant from Jupiter; and he concluded they could

* Gaſſendi Opera, Tom. IV. p 511.

† Novæ Cœleſtium & Terreſtrium Rerum Obſervationes.

not

not be fixed Stars, becauſe he lengthened the Tube of his Teleſcope when he looked at theſe Satellites, whereas he contracted it when he viewed the fixed Stars. *Zupus* went ſtill farther, and aſſerted in a Letter to Ricciolus, dated February 4th, 1644, that he had ſeen to the Number of *twelve* Satellites, and ſent him a Delineation of their Situations and Diſtances. And though Reinerus had aſſured Ricciolus upon this Occaſion, that he himſelf, in ten Years Obſervations, had never ſeen but *four*; yet Ricciolus, when he publiſhed his Almageſt in 1651, was ſo puzzled with theſe various Accounts, that he would not venture to give an Opinion which of his Friends the Aſtronomers were in the Right, and therefore choſe to

pronounce upon this Queſtion in the Words of the Roman Prætors when they were at a Loſs how to determine a Cauſe, *Amplius, quia non liquet* *.

In this State of Uncertainty it was ſome Time before the Theory of the Secondary Planets came to be regularly reduced into Tables; and though *Simon Marius* firſt, and after him *Baptiſta Hodierna*, compoſed Ephemerides of their Motions, yet nothing of that ſort was found to be ſufficiently accu-

* Proinde cum veritas nondum manifeſta mihi ſit, quæ amicitiæ prævaleat; nolo litem dirimere inter amicos aut ullam de hac re ſententiam pronunciare; ſed potius cum Romanis Prætoribus ad antiquam me formulam illum redigere, *Amplius, quia non liquet.* Riccioli Almageſt. Vol. I. p. 490.

rate

rate for the Purpoſes of Longitude, till M. *Caſſini* publiſhed his Tables of the Revolutions and Eclipſes of the Satellites in 1668 *.

The firſt Opportunity of effectually applying this Theory to the rectifying of Geography, was ſuggeſted by M. Caſſini, and taken by M. Picard in the Years 1671 and 1672, who made a Voyage for that and other Purpoſes to *Uraniburgh*, the Obſervatory of *Tycho Brahé*, which was ſituated in the little Iſland of *Huena* in Denmark, being in the Entry of the Baltick, betwixt Copenhagen and the Sound. He there obſerved two Immerſions

* Fontenelle's Eloge de M. Caſſini dans les Mémoires de l'Académie des Sciences pour 1712.

and three Emerſions of the firſt Satellite of Jupiter, which were afterwards compared with the ſame obſerved by M. Caſſini at the Obſervatory at Paris. The two Immerſions were on October 25th 1671, and January 4th 1672; the three Emerſions were on March 14th, March 29th, and April 6th 1672. The Mean of all which, compared with thoſe of Paris, gave a Difference in Time of 42′ 10″, being equal to 10° 32′ 30″ Difference of Longitude. The Teleſcope uſed at Paris was 18 Feet long, that at Uraniburgh 14 Feet; both of which had nearly the ſame magnifying Power.

It was then apparent how ineffectual all the former Methods had proved

for

for determining this Queſtion, as *Kepler*, who preferred the Eclipſes of the Sun, had calculated the Difference of Longitude half a Degree too little. *Ricciolus* had made a Miſtake of almoſt a whole Degree too much; and *Bullialdus* and *Longomontanus*, who had obſerved ſo many Lunar Eclipſes at Paris and Copenhagen, had made a ſtill greater Error of one Degree and a Half*.

I have been the more particular in explaining minutely this firſt Experiment made by means of the Satellites, becauſe it gave at once the Difference of Longitude in the cleareſt Manner beyond the Poſſibility of a

* Voyage d'Uranibourg par M. Picard. p. 28.

Doubt; and it likewiſe communicated the certain Proſpect of rectifying the whole Extent of Geography as to Longitude, upon Principles that were ſelf-evident, and not liable to any Miſtake whatever.

In conſequence of this Succeſs, Meſſieurs Picard and De la Hire, two of the French Academicians, were immediately employed in examining and correcting *the Map of France*; in doing which they were obliged to contract it every where within leſs Boundaries than it was ſuppoſed according to their former Maps to have occupied *, paring off *one Degree* and upwards

* The Outline of the two Maps is publiſhed dans le *Récueil d'Obſervations pour perfectionner l'Aſtronomie*

upwards of Longitude from the Weſtern Capes of *Bretagne*, and from thence Southward nearly the ſame Quantity all along the Coaſt of Poictou, Guienne and Gaſcogne, to the Bottom of the *Bay of Biſcay*,; and in like Manner they cut away *half a Degree* from the Shores of *Languedoc* and *Provence*; which gave occaſion to Lewis XIV. to tell them in Joke upon their return, *That he found by their Journey he had ſuffered a Loſs of Part of his Kingdom* *.

Other Academicians determined by the ſame Method the Longitudes of

l'Aſtronomie & la Geographie, par Meſſieurs de l'Académie Royale des Sciences. Paris 1693.

* Fontenelle's Eloge de M. De la Hire, dans les Mémoires de l'Académie des Sciences pour 1718.

the Iſle of Gorée, near Cape Verd, on the Coaſt of Africa, and of Guadaloupe and Martinico in the Weſt Indies *. And as M. Caſſini had greatly improved his Tables of the Satellites of Jupiter, and publiſhed a new Edition of them in 1693, it was then thought proper to ſend *M. Chazelles* up the Levant, to obſerve the Longitudes and Latitudes of Scanderoon, Alexandria and Conſtantinople, in order to determine the Length and Breadth of the Mediterranean, which he executed with great Ability.

* *Obſervations Aſtronomiques*, p. 65. dans le Récueil d'Obſervations pour perfectionner l'Aſtronomie & la Geographie.

The

The Longitude of Alexandretta, or Scanderoon, was found by him to be 34° 15′ East of the Meridian of Paris, from a Tranſit of the firſt Satellite of Jupiter over the Body of that Planet, January 14th 1694, from a Conjunction of the firſt and ſecond Satellite which happened the ſame Day, and from two Emerſions of the firſt Satellite which happened on the 22d and the 28th of the ſame Month; all of which being compared with the ſame Obſervations made at Paris by M. Caſſini, gave a Difference in Time of two Hours and ſeventeen Minutes, which being reduced to Space, gave the Longitude as above-mentioned *.

* Mémoires de l'Académie des Sciences pour 1721, p. 75.

The other Part of the Longitude of the Mediterranean, containing that Diviſion of it from the Meridian of Paris to the Straits of Gibraltar, has not hitherto been ſo accurately determined. M. Deſliſle mentions in a *Memoire* * drawn up for the Information of the Duke of Orleans, then Regent of France, "That no aſtronomical Obſervations had been made "for aſcertaining this Diſtance prior "to the Year 1720;" he had therefore, by the Aſſiſtance of the Sea Charts, made it to be 7° 30′ from the Meridian of Paris to that of Gibraltar, having conſidered Algiers to be 1° 25′ to the Eaſtward of that of Paris. But

* Mémoires de l'Académie des Sciences pour 1720, p. 477.

by

by an Eclipſe of the Moon obſerved at Algiers by the Miſſionaries of St. Lazare, on Auguſt 8th 1729, mentioned by M. De la Condaminé *, it would ſeem that Algiers was 7′ 15″ to the Weſtward of Paris, which makes a Difference of 1° 32′ 15″. So that there will a Doubt ſtill remain with regard to the exact Situation both of Gibraltar and Algiers; and they may therefore be ſuppoſed to be included under M. Deſliſle's Remark †, "That "there

* Mémoires de l'Académie des Sciences pour 1732, p. 404.

† Il y a dans l'Univers beaucoup de lieux eſſentiels à la Geographie & à la Navigation, dans leſquels on n'a pas encore fait aucune obſervation pour en fixer la ſituation, & nous avons pluſieurs autres lieux obſervés, dont les circonſtances

"there are many Places upon the "Earth, the Knowledge of whoſe Si- "tuation is eſſentially neceſſary for "Geography and Navigation, in "which there has been no Obſer- "vation as yet made for that Pur- "poſe; and there are beſides many "other Places, which, though they "have been obſerved, yet certain "Circumſtances attending the Ob- "ſervation have rendered the Deter- "mination doubtful."

Since the Correction of Longitudes has been introduced by means of the Satellites of Jupiter, other Methods

ſtances on rendent la determination douteuſe. Mémoires de l'Académie de Sciences pour 1720, P. 474.

have

have alſo been adopted and deviſed, which are proper and effectual for that Purpoſe; ſuch as *the Tranſits of Mercury* and *Venus* over the Body of the Sun; *Occultations* of the fixed Stars by the Moon: And ſince *the Lunar Tables* have been improved by M. *Mayer*, another large Field has been opened equally applicable to this important Object, by meaſuring from time to time the exact *Diſtances of the Moon from the Sun*, and *from a fixed Star* of the firſt and ſecond Magnitude. Each of which Obſervations being carefully compared one with another, are like ſo many new Experiments which muſt either confirm or contradict the Longitudes that have been already obſerved. There is one fortunate Circumſtance likewiſe attends all theſe

various

various Methods, which is, that when they happen to differ in their Concluſion, there is always a *Limitation of Error* pointed out, which gives ſo far a Degree of Satisfaction, and prepares the Way for bringing the Point that is thus unſettled, to a more ſpeedy and certain Determination.

In explaining the Miſtake of Ptolemy in his over-rating the Length of the Mediterranean by upwards of one thouſand Miles, and in ſhewing likewiſe the Method of its Correction, I have been gradually induced to trace the ſucceſſive Improvements that have been introduced in taking the Longitude from that Period down to the preſent Times. It will not therefore be improper to give as a

Counter-

Counterpart ſome Account of *the Time and Manner of rectifying the Latitudes of different Places.*

Little was done in Geography from the Days of Ptolemy to the Reſtoration of Learning in Europe, for the Arabian Geographers copied and retailed all his principal Errors. They obſerved indeed, under their Caliph Almamon, in the Beginning of the IXth Century, a Degree of Latitude on the Plains of Sinjar, or Shinar, near Babylon *, and found it to meaſure

* Greaves, in his Preface to Abulfeda's geographical Deſcription of Chorazmia, &c. being the Countries beyond the River Oxus, printed, London 1650, at the End of his *Epochæ Celebriores*, has theſe Words: *Abulfeda alibi refert*

ſure $56\frac{2}{3}$ Arabian Miles, each of which conſiſted of 4000 Cubits, or 6000 Feet, from which they determined the Circumference of the Earth.

When Science began to be revived in Europe, it was ſome Time before the Aſtronomers of that Age were able to obtain Copies of Ptolemy's

refert Aſtronomos juſſu Almamonis in Campis Sinjar, prope Babylonem, ex Obſervationibus deprehendiſſe LVI *Milliaria & $\frac{2}{3}$ uni gradui competere.* Ricciolus, in his Almageſt, Tom. I. p. 61. quotes Alfraganus as ſaying, that this Menſuration was made on the Plains of Fingar, adjoining to the Red Sea. *Almæon Rex Arabum ut refert Afraganus — convocatis pluribus Sapientibus Geometris juſſit eos in Campis Fingar juxta rectum iter Maris Rubri explorare, quot Milliaria inſint uni Gradui Meridiani Circuli, &c.*

Geography;

Geography; and even then it was with Difficulty they could read and clear the Manuſcripts of ſome of their groſſeſt Errors: For wherever Numbers were inſerted in any Author, and made the Bulk of the Compoſition, the Miſtakes were generally multiplied more abundantly in the tranſcribing; becauſe the Senſe did not there, as in moſt other Books, by a Kind of Self-evidence, aſſiſt the Copier in preſerving the Authenticity of the Original.

It required likewiſe ſome longer Space of Time before the Aſtronomers conſtructed proper Inſtruments, in order to try whether theſe Latitudes ſo recorded, correſponded with the Situations as they really ſtood in Nature.

ture. But when they came actually to obſerve them, they diſcovered the Latitude of many Places materially different from what had been ſet down by Ptolemy; and finding this Variation in ſome of them to be nearly of the ſame Quantity, inſtead of accounting for this Difference from the Imperfection of Inſtruments, the Inaccuracy of Obſervers, and the Method of Ptolemy's Converſions, which I have already explained, they haſtily concluded that the Axis of the Earth had ſhifted its Poſition, by which the Latitudes of all the Places in Europe had been increaſed. This was the Idea of Dominicus Maria of Ferrara about the Year 1489*, who fancied

* Snellii *Eratoſthenes Batavus*, lib. 1. p. 41.

that

that the Variation was at the Rate of one Degree in 1050 Years; ſo that after a long Revolution of Ages, it would happen that the Countries now under the frigid Zone ſhould be found in the Torrid; and that in like Manner thoſe Regions which ſuffer from the Violence of the Heat, ſhould gradually paſs into the temperate and frigid Zones. Men of warm Imaginations might eaſily work up this Dream of Geographers into a beautiful and an equitable Diſpoſition of Nature *.

This

* Some of the Geographers among the Ancients had given ſome Countenance to this ſingular Notion. Strabo tells us, lib. 2. p. 68. in the Beginning of his Second Book, that Eratoſthenes was of Opinion that the Mountains of

This Hypotheſis was again adopted by Maginus of Bologna, about a hun-

of Aſia were not then found to lie in the ſame Situation in which the ancient Maps had placed them, but had ſhifted towards the North, and that India had been attracted in the ſame Manner, and was become more northerly than before. Πολὺ γὰρ ἐπὶ τὰς ἄρκτους παραλάττειν τὰ ἑωθινὰ μέρη τῶν ὁρῶν κατ' αὐλον, συνεπισπᾶσθαι δὲ καὶ τὴν Ινδικὴν ἀρκτικωτέραν ἤδη γινομένην.

Pliny likewiſe, lib. 36. cap. 10. when he mentions the *Obeliſk* which was erected in the *Campus Martius* at Rome, by means of which they determined the Lengths of the Days, and their Variations, ſubjoins, that the Obſervations for the laſt thirty Years did not anſwer, from ſome Change in the Heavens, or in the Poſition of the Earth, and which had been taken notice of in other Places. *Hæc Obſervatio triginta jam ferè annis non congruit, ſive Solis ipſius diſſono curſu, & cæli aliqua ratione mutato, ſive univerſa tellure aliquid a centro ſuo dimota, ut deprehendi & in aliis locis accipio, &c.*

dred

dred Years after, towards the Cloſe of the XVIth Century, in which he had the Concurrence of ſeveral of the Italian Aſtronomers. And their Authority made ſuch an Impreſſion upon Tycho Brahé, that being deſirous of clearing up a Doubt which he thought had ſome Foundation, he therefore applied to the Republick of Venice * to ſend ſome good Obſervers into Egypt, to verify whether the Height of the Pole was ſtill the ſame at Alexandria as it had been found by Ptolemy. For as that City had been formerly as it were *the Metropolis of Aſtronomy*, there could be no doubt but that the Height of the

* M. Caſſini dans les Mémoires de Mathématique & Phyſique de l'Académie, R. de Sciences de 31 Juillet 1693, p. 116.

Pole

Pole there muſt have been accurately obſerved for a long Series of Years by their ableſt Aſtronomers, and that Ptolemy muſt have examined it himſelf with his utmoſt Attention before he had made uſe of it in his Aſtronomical Calculations; but Tycho's Requeſt was not then complied with. However, when the Obſervation was made, it did not ſufficiently ſupport their Hypotheſis; for Ptolemy having found Alexandria to be 30° 58′ according to his Almageſt *, or 31° according to his Geography †; the Obſervations made ſince by Mr.

* Ptolemæi Mathem. Syntax. lib. 5. cap. 13. p. 123.

† Ptolemæi Geogr. lib. 4. p. 103.

Greaves

Greaves* in 1638, made it amount to 31° 10′, and thoſe by M. Chazelles in 1694, and by M. Condaminé in 1731†, fix it at 31° 11′; which though a Variation of eleven or thirteen Minutes, may be charged, as in many other ſimilar Caſes, upon the Errors of Inſtruments and Obſervers.

Peter Petit, a Mathematician of ſome Eminence in France, endeavoured to revive this Opinion in a Diſſertation‡ publiſhed in 1660, *from the*

* Greaves's Works, Vol. II. p. 513. Dr. *Birch* ſays in a Note there, that in other Places of the MS. our Author makes it 31° 5′ and 31° 3′.

† Mémoires de l'Académie des Sciences pour 1721, p. 75. & pour 1732, p. 404.

‡ P. Petit in Epiſtola ad Sauvallum, De Latitudine Pariſienſi. Caſſini dans les Mémoires

the apparent Variations in the Latitude of Paris, as taken by the ableſt Aſtronomers, ſome of whom had made it 48° 39′, others 48° 45′, ſometimes 48° 50′, and at other times 48° 55′. All of which only confirms an Obſervation made by an eminent French Aſtronomer, that they had no good Quadrant fit for taking an Obſervation of the Latitude, even in the whole Kingdom of France, in the Year 1664. For M. *Auzot*, in a Letter which he addreſſed to Lewis XIVth in this very Year, made uſe of the following Words: *Mais, Sire, c'eſt un Malheur, qu'il n'y a pas un Inſtrument à Paris, ni, que je ſçache, dans tout*

moires de Mathem. & Phyſique pour 1693, p. 117.

votre

votre Royaume, auquel je vouluſſe m'aſſurer pour prendre preciſement la Hauteur de Pole *.

The Latitude of *London* was known much ſooner than that of *Paris*, and brought to a greater Degree of Accuracy; for it was determined by *Edward Wright*, who is otherwiſe diſtinguiſhed as the original Inventor of what is called *Mercators Chart*, by Obſervations made in 1593 and 1594, from the greateſt and leaſt Height of the Pole Star, and found to be 51° 32′ †, taken by a Braſs Qua-

* Aſtronomie de M. De la Lande, Vol. II. p. 842.

† Horrocii Opera Poſthuma, p. 51, & p. 70.

drant of ſix Foot Radius; before that Time the Latitude of London was ſuppoſed to be 51° 45′ in all the Maps of that Age. And though this Obſervation was made at a Time when the Error from Refraction had been juſt diſcovered by Tycho, and not fully known, yet it is allowed to be juſt and exact even now, when the Inſtruments which are conſtructed at preſent enable Obſervers to come to the utmoſt Preciſion of Seconds.

Nothing can be a ſtronger Proof of the Coarſeneſs of all the Obſervations, both in Aſtronomy and Geography, prior to the Days of Tycho, than the Ignorance of Aſtronomers with regard to the Error ariſing from *Refraction*; for this occaſions a Miſtake

at

at the Horizon of no leſs than 33′ 45″, and is found in all the intermediate Altitudes, though gradually leſſening, up to the Zenith. When Tycho firſt diſcovered it *, by uſing better Inſtruments than former Obſervers, he erroneouſly ſuppoſed that the Sun had no Refraction when he was above *forty-five Degrees high*, and that the Stars had none when their Height was upwards of *twenty Degrees* †; whereas the Refraction is now found, by more accurate Experiments, to be the ſame in both: And that though this diminiſhes imperceptibly, yet it never

* Gaſſendi Opera, Tom. V. p. 423 & 4.

† Tycho likewiſe ſuppoſed that the Sun's Refraction *at the Horizon* was 34′, but that of the Stars only 30′.

vaniſhes intirely, till they are quite vertical.

It muſt be allowed, indeed, that ſome of the Aſtronomers before his Time had taken notice of it, as altering the apparent Places of the Stars; but they had a very imperfect Idea both of the Principles on which it was founded, and of the Quantity of the Error which it produced. *Roger Bacon*, who flouriſhed in the XIIIth Century, tells us*, "*That the Stars*

* Nam ſi quis per inſtrumenta, quibus experimur ea quæ ſunt in cœleſtibus, cujuſmodi vocantur armillæ vel alia, accipiat *locum alicujus Stellæ* circa æquinoctialem *in ortu ſuo*, & deinde accipiat locum ejuſdem quando venit *ad lineam meridiei*, inveniet in loco meridiei *diſtare eam ſenſibiliter plus a polo mundi ſeptentrionali, quam quando fuit in ortu.* Rogeri Baconis Specula Mathematica, p. 37.

"*appeared*

"*appeared ſenſibly to be at a greater Di-*
"*ſtance from the North Pole when they*
"*were in the Meridian, than at the Time*
"*of their Riſing.*" In his accounting for it, he diſtinguiſhes betwixt the perpendicular and the oblique Rays, and tells us, that *Ptolemy*, Lib. V. *De Opticis*, and *Alhazen*, Lib. VIII. were of the ſame Opinion. But when he endeavours to explain his Ideas more particularly, he introduces his Theory of *the Spheres of Air and of Fire*, which was *the Mode in Philoſophy of thoſe dark Ages*, and has been long ago exploded.

After Tycho had diſcovered the Error and the Quantity of Refraction as he imagined, he was then deſirous of knowing whether *Copernicus*,

from an Omiſſion of this neceſſary Deduction, had not been deceived in the true Latitude of *Fruenburgh*, the Place of his Reſidence, at the Mouth of the Viſtula, where it diſcharges itſelf into the Baltick; and if ſo, then he concluded that all his other Obſervations muſt be ſo far erroneous, and require to be corrected by the ſame Deduction. He therefore ſent *Elias*, one of his Scholars, with proper Inſtruments, thither in 1584, who found that the Latitude of Fruenburgh had been really miſtaken no leſs than three Minutes, as it was obſerved to be 54° 22′ and ½, inſtead of 54° 19′ and ½, according to Copernicus *. At *Konigſberg*

* It is remarkable that Copernicus had made nearly the ſame Miſtake in *the Sun's Declination*, that

nigſberg likewiſe, where *Eraſmus Reinholdus* had lived and publiſhed his *Tabulæ Prutenicæ*, Elias diſcovered in the ſame manner that this Aſtronomer had been miſled by Peter Appian, ſo as to be miſtaken twenty ſix Minutes, which was near half a Degree; for the Latitude of that City was found to be 54° 43′ inſtead of 54° 17′, which Reinholdus had adopted in his aſtronomical Tables *.

that he had done in the Latitude of Fruenburgh, being an Error of betwixt two and three Minutes, ariſing in both Caſes from his not making Allowances for the Refraction. Copernicus, in lib. v. Revolutionum, cap. 30. comparing his Situation at Fruenburgh with Alexandria, makes uſe of the following Words: *Ptolemæo, Alexandriæ ſerenitatem & aëris puritatem plurimum faviſſe, cum ipſe locum incoleret, fœdum nebulis & viſtulæ vaporibus præpinguem.*

* Gaſſendi Operá, Tom. IV. p. 410.

It is ſomewhat remarkable, that when M. Picard, the French Aſtronomer, went to Uraniburgh in 1672, he ſeemed to make *a fair Reprisal* upon Tycho in return for his detecting the Errors in Latitude of Copernicus and Reinholdus. For though Tycho was at infinite Pains in determining the Latitude of Uraniburgh to be either 55° 54′ 30″, or 40″, or 45″, being in an Uncertainty betwixt theſe three Numbers *; yet M. Picard, by a Variety of the moſt accurate Obſervations, diſcovered that all of them were too much, and that the leaſt of them had a Miſtake of one Quarter of a Minute, as the real Latitude of Uraniburgh was exactly 55° 54′ 15″.

* Voyage d'Uranibourg, p. 17.

He

He found a ſtill greater Error in Tycho's Meridian Line.*, amounting to no leſs than 18′ or 20′, as the true Meridian was found to be ſo much to the Weſt of the North of that which reſults from the Poſitions given by Tycho.

The French Aſtronomers ſeemed to think that their Advantage over Tycho, in theſe particular Obſervations, aroſe from an Improvement made a few Years before, in 1667, by having a ſmall Teleſcope fitted upon their Quadrants and Sectors inſtead of the Pinnulæ or Sights, which were in uſe before that Time; by which means they were enabled to take the Angles

* Voyage d'Uranibourg, p. 11.

and Altitudes with a ſuperior Degree of Exactneſs.

But however flattering it was to the Vanity of the French Aſtronomers to have diſcovered and corrected the Errors of ſo eminent an Obſerver as Tycho, yet we may reckon it as the Happineſs of the preſent Age that ſo many new Improvements have been made in Inſtruments of all Sorts ſince that Time, by which the Progreſs in Aſtronomy and Geography has been quickened much beyond the Ideas of our Forefathers. Quadrants and Sectors are now ſo accurately divided, that the Eye can ſcarce diſtinguiſh ſo exactly as it is performed by the Inſtrument; ſo that in order to *read* the Obſervation with the Preciſion

with

with which it is executed, we muſt take the Aſſiſtance of magnifying Glaſſes, the Diviſions of Nonius, and thoſe circular Micrometers where the Revolution of the ſmall Thread of a Skrew is divided into 360, or any other aliquot Parts of a Circle. And if any one Country can claim a Merit in having diſtinguiſhed itſelf more eminently than another in theſe Improvements, it is this Kingdom, where the beſt Inſtruments of Obſervation have been acknowledged to be made for upwards of half a Century.

There is another Particular hitherto unmentioned, which has greatly contributed to the ſolid Advancement both of Aſtronomy and Geography, and this is the more accurate Method

now practiſed for *the meaſuring of Time*, which though in appearance of a different Nature, is equally capable of being applied to *the Menſuration of Space*. For in the Tables of Longitude it is well known that Time and Space are uſed like two different Languages, where the ſame Truth is expreſſed with equal Clearneſs in both, though in Characters that are eſſentially different from each other; as one Hour in Time is allowed to be equal to fifteen Degrees in Space upon the Surface of the Earth, and of courſe all the aliquot Parts of each are in the ſame Proportion.

Sun Dials and *Clepſydræ*, or Water Clocks, were the principal Meaſures of Time among the Ancients. It

It was only about the Year of Chriſt 1300, that *Clocks with indented Wheels* are ſaid to have been firſt in uſe. And it was not till 200 Years after this that they ſeem to have been employed for the Purpoſes of Aſtronomy. For Waltherus, the Diſciple of Regiomontanus, is ſaid to have had one about the Year 1500; which Schoner, who publiſhed his Obſervations in 1544, ſays, was ſo regular, that from Mid-day to Mid-day it perfectly agreed with the Sun, and was almoſt as exact in the Times given, as in thoſe drawn from Calculation. Tycho Brahé is ſaid to have had four Clocks which marked Minutes and Seconds, the largeſt of which had only three Wheels; the Diameter of one of them was three

Feet,

Feet, and it had 1200 Teeth *. But all of thoſe were exceedingly imperfect, till Monſieur Huyghens improved them in 1656, by his Invention and Application of *the Pendulum*, whoſe Vibrations were regular and iſochronical. The Improvements that have been ſince made in *Clocks* and *Time-pieces*, and the Manner in which they have been applied to the Determination of Longitude, is a Branch of Knowledge that will be beſt learned from the Books which have been profeſſedly wrote upon this Subject.

It was never my Intention in this Diſſertation to enter into the Diſcuſſion of the preſent State of Geogra-

* De la Lande's Aſtronomie, p. 917, &c.

phy,

phy, or to give the comparative Excellence of the Maps of different Countries. The Field is much too large to be attempted without better Materials and more Leiſure than I am now Maſter of. It has, beſides this, been already executed with great Ability and Knowledge by M. *Robert de Vaugondy*, in the Introduction which he has prefixed to his *New Atlas*.

I muſt, however, obſerve upon the whole, that Geography is a Science even ſtill many Stages removed from Perfection. The Maps of America, and the Eaſtern Parts of Aſia, though they have been of late two of the great Theatres of War and Commerce, are perhaps more unfiniſhed than any of the reſt. Every new Map

that

that is publiſhed of theſe Countries, ſeems to blaſt all thoſe that went before them, and it will require perhaps the Experience of half a Century to come, before a ſufficient Number of Obſervations ſhall be made to verify the Situations of their moſt conſiderable Towns, Coaſts and Rivers, ſo as to approach the Accuracy with which the Maps of the different Kingdoms of Europe are now executed.

And yet upon this Occaſion, I muſt confeſs, that even the Maps of Great Britain and Ireland are ſtill very imperfect and unſatisfactory; and the Numbers we have of them, varied and re-publiſhed without any real Improvements, juſtly confirm an Obſervation which Lord Bacon has wiſely made

made in a ſimilar Caſe, "*That the* "*Opinion of Plenty is one of the Cauſes* "*of Want* *." The late Dr. Bradley was of Opinion, that there were but two Places in England whoſe Longitude might be depended upon as accurately taken, and that theſe were *the Obſervatory at Greenwich*, and *Sherborn Caſtle*, the Seat of the Earl of Macclesfield in Oxfordſhire, and that their Difference was one Degree in Space, or 4′ in Time; but even this has been found to be inaccurate by the late Tranſit of Venus, as being only 3′ 47″ †. If we ſhould examine the Longitude of *the Lizard*, we ſhall

* Bacon de Augmentis Scientiarum Prelim. § 4.

† Philoſophical Tranſactions for 1762, vol. lii. p. 624.

ſcarce

ſcarce find two Geographers of the ſame Opinion. In the Account of Longitudes prefixed to Halley's Tables, it is ſaid to be 4° 45′ from the Obſervatory, which is therefore 4° 40′ from London; according to others it is 5° and 5° 5′, and by ſome 5° 14′ *, and by others it is enlarged even to 6°; this ſurely is a Matter worthy the publick Attention, when we conſider that it is a Point of Land the moſt important of all others to the Navigation of this Kingdom †.

* Robertſon's Navigation, vol. i. p. 378.

† This is held to be ſo uncertain, that Sailors when they approach the Mouth of the Channel, generally think it ſafeſt to *grope* their way *by Soundings*, rather than depend upon Obſervation or Calculation.

I ſhall

I ſhall therefore conclude this Diſſertation with obſerving, that all Maps in general ought to be conſidered as *unfiniſhed Works*, where there will be always found many things to be corrected and added, and that they ought to have a Kind of *floating Title* affixed to them, expreſſive of their imperfect State, ſimilar to what Pliny tells us was practiſed by the greateſt Painters and Statuaries of Antiquity; ſuch as, *Apelles faciebat aut Polycletus*, but not *fecit*; claiming an Indulgence to the Artiſt, as if he was employed to his laſt Moments in correcting the Faults of his Compoſition, *tanquam inchoata ſemper arte & imperfecta, ut contra judiciorum varietates ſupereſſet artifici regreſſus ad veniam, velut*

velut emendaturo quicquid desideretur, si non esset interceptus *.

* Plinii Præfatio Nat. Hist. ad Divum Vespasianum.

FINIS.